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Economic performance, technical efficiency and fishers' perceptions of factors affecting fishing activities

A study of a Vietnamese purse seine fleet

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A dissertation for the degree of Philosophiae Doctor, February 2022

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Acknowledgement

First, I would like to thank my dear family, my husband and our darling daughter and son, and my mother and my parents-in-law for their support and encouragement during my PhD study. This PhD work has been completed thanks to their huge sacrifice and love.

I would like to express my great gratitude to my main supervisor and co-author, Professor Arne Eide, who has guided me throughout the three scientific papers and the PhD thesis. I am grateful for your close supervision. Your kindness, your patience, and your belief in me are much appreciated. My PhD study would never have been completed without your kind support and your great help.

I would like to express the deepest and most sincere thanks to my co-supervisor, and co-author, Professor Claire W. Armstrong, who has encouraged me, giving me good suggestions, and has been a great help during my PhD journey. She has also greatly contributed to the knowledge of the two papers, as well as the guidance and comments on the thesis. This dissertation has been finished thanks to your great support, and your big help, as well as your proofreading.

I would like to thank my co-supervisor, and co-author, Associate Professor Le Kim Long, who has encouraged me and contributed to the knowledge and the research materials for the first two papers. This dissertation would never have been finished without your kind discussion and support.

It is a pleasure to thank the Director of UiT The Arctic University of Norway and my colleagues at the Norwegian College of Fishery Science, Biosciences, Fisheries, and Economics Faculty, UiT The Arctic University of Norway. You have enriched my PhD work and my social life. Special thanks to Professor Ola Flaaten, Associate Professor Margrethe Aanesen, Associate Professor Eivind Hestvik Brækkan, Professor Knut Heen, Associate Professor Yajie Liu, Dr Jan-Eirik Angell Killie, Professor Peter Arbo, Kristoffer Kokvold, Kathrine Tveiterås, Tone

Osnes, Kari Nordeng Mellem, Ingjerd Gauslaa Nilsen and Rune Larsen for their concern, enthusiasm, support and all the help during my stay in Tromso.

I would like also to thank Associate Professor Trang Si Trung – Director of Nha Trang University, and the administrative staff at Nha Trang University, Norhed project-Nha Trang University, and my colleagues at the Faculty of Economics, Nha Trang University, for their encouragement, concern, support and all their help during my PhD study. Moreover, I would like to thank my colleagues at the Economics Department for assuming my teaching responsibilities during my absence. Special thanks to Associate Professor Nguyen Thi Kim Anh who has encouraged me to pursue a PhD in natural resource economics and her strong confidence in me.

I also acknowledge the Norwegian Agency for International Development Cooperation (NORAD), Norhed Project SRV-13/0010, which has provided the financial support for the data collection for my PHD thesis, studies and travels between Vietnam and Norway as well as attending the international conferences in the USA and Canada during my PhD study.

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List of papers

Paper I:

Cao Thi Hong Nga, Arne Eide, Claire W. Armstrong, Le Kim Long.

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Paper II:

Cao Thi Hong Nga, Arne Eide, Claire W. Armstrong, Le Kim Long. Measuring technical efficiency in fisheries using physical or economic variables: A data envelopment analysis of a Vietnamese purse seine fishery.

Paper III:

Cao Thi Hong Nga, Arne Eide. Fishers' perceptions of negative events affecting fishing activities. A case study of a Vietnamese purse seine fishery.

Summary

The focus of this thesis is on the economic performance and technical efficiency of a Vietnamese fishing fleet by the use of data envelopment analysis (DEA). The double bootstrap method has been used to overcome some of the limitations of DEA. In addition, the dissertation evaluates fishers' perceptions of negative events affecting the fishing activities.

The first of three papers presents the investigated fleet and the economic performance in 2016 under open access conditions. Fixed and variable costs, and revenue have been used for estimating the technical efficiency. By adopting double bootstrap DEA under the hypothesis of variable returns to scale, the average technical efficiency of the fleet is found to be relatively high. Nevertheless, the DEA calculations showed that the current catch level could be obtained by a fishing effort 24–35% lower than the actual vessel activity. Vessel size and fishing experience are all factors affecting the technical efficiency.

The second paper measures and compares the technical efficiency using physical vs. economic measures. The study focuses on the same 52 Nha Trang purse seiners as in the first paper. Adopting the double bootstrap DEA method, the findings show that economic measures give a lower level of technical efficiency than that which is obtained by physical measures. However, there is significant difference in the technical efficiency between these two measures. The skipper's experience and interest payment significantly affects the physically based technical efficiency at the 5% level. This study concludes that physical variables, which are often more accessible, are capable of capturing essential economic differences between vessels.

The third paper studies the same purse seine fishers' perceptions of how environmental and socio-economic factors influence their life and fishing activities. The findings are that storms/cyclones, severe floods, heavy rains, high temperature, big waves and bad weather reduce fish density, and the poor availability of capital, health conditions and crew access all negatively affect fishing activities. The fishers' perceptions of the increased temperature and declining fish stocks over time are in line with available data, whereas their perceptions of the frequencies of storms, floods and heavy rains differ from the observations. Despite increasing frequencies of storms and precipitation not actually observed, the fishers perceive such factors as creating problems for their current fishing activities.

Almost all the fishers in the sample expected the frequency and severity of rainfalls and the average temperature to increase in the future, while fish stock availability will decline. However, climate change is not expected to be among the most important negative factors in the future. Cost of fishing, health conditions, efficient fishing gear and boats, as well as the resource situation, represent important factors causing greater concern among fishers regarding future fishing activities.

PART 1. INTRODUCTION

1. Research problems and objectives of the thesis

Fishers are considered to be profit-seekers. With open access to enter fisheries this may have long-term negative impact on the utilized resources. The fishing industry will grow as long as profit extracted exceeds normal profit in an open access fishery (Gordon, 1954). Scott Gordon's seminal paper (op. cit.) also shows that given his biological assumptions, in the long run only the most cost-efficient vessels will remain in an open-access fishery. Hence, the standard theory suggests the fleet in the long run will develop towards homogeneity. However, quasi rent and intra marginal rent may exist in most fisheries due to natural and market fluctuations not covered in the simple model. A more realistic model including natural and market fluctuations will lead to fleet diversity and varying degrees of abnormal profits, also in the open-access situation. This thesis presents a Vietnamese purse seine fleet operating in a de facto open-access situation, aiming to investigate efficiency variations as a function of physical and social differences.

Fifty-two purse seiners from a port in Vietnam, in a country of more than one hundred thousand other fishing vessels, are the selected focus of the thesis. Most of the purse seiners are family businesses providing food and income to the family. The fishing operations are affected by natural fluctuations, and market dynamics affect the income. The fleet diversity reflects differences in culture and professionalism. The purse seine fleet has recently been transformed and is now dominated by larger vessels than before. Consequently, the average vessel engine size has tripled during the period from 2009 to 2016 (DECAFIREP, 2010, 2016). The recent development in fleet structure indicates an increased fishing capacity in spite of a slight (3%) decline in the number of vessels. The fleet has probably become less homogeneous after the recent changes, and these changes occurred due to governmental subsidies. The subsidies are motivated by the aim to increase fishing efficiency and also to protect national interests and sovereignty of territorial waters.

Increased fishing efficiency of the purse seine fleet may potentially impose higher pressure on the fish stocks. Advances in fishing technology (larger boats, modernized fish-finding equipment, etc.) also contribute to increasing the fishing capacity of the fleet as well as increasing the competition among the participants under open-access conditions (Pomeroy et al., 2009).

Excess fishing capacity has become a major obstacle to sustainable fishing, causing stock decline and increasing the cost per unit of harvest. To balance between the fish resources and the harvesting capacity of the fleet, it is necessary to understand the harvesting efficiency of the fleet. Efficiency can be changed due to the introduction of new technology or changes in fishing practices or management by imposing restrictions on input use (for example, mesh size used). Furthermore, managers need to understand how existing management interventions are affecting this harvesting capacity.

The effect of the various factors (vessel characteristics, such as hull length; socio-economic conditions of fishers, such as skippers' experience; loans) on the harvesting capacity can be measured through the analysis of the technical efficiency in the fishery. The main aims of the dissertation are to investigate economic performance of the purse seine fleet, and determine the technical efficiency in this important fishery.

Data envelopment analysis (DEA) is often preferred over the stochastic production frontier (SPF) method for estimating the efficiency in fisheries (Castilla-Espino et al., 2006; Kirkley et al., 2002, 2004; Pascoe and Tingley, 2016). DEA studies of fisheries usually assume output-oriented technical efficiency based on physical measures. Physical measures capture important input factors employed in fishing activities (such as boat size and engine power), whereas economic measures directly reflect the cost of inputs employed. To investigate whether economic measures are necessary for efficiency analysis or sufficiently well reflected in the use of physical measures, fishing vessel technical efficiencies have been estimated and compared using both physical and economic variables in this dissertation. The bootstrap technique has been applied to overcome some of the limitations related to the DEA method.

Fishing is an important livelihood activity for coastal communities and takes place within a shifting natural environment. Fishing is difficult or impossible during storm and cyclone periods, during flooding, heavy rain and big waves. Fishing activities are also affected by other natural events, such as seasonal variation, ecosystem perturbations and, of course, changes in fish distribution and abundancy. Social and economic factors, such as market changes and the living conditions in general, also affect fishing activities in different ways.

Vietnam is considered to be among the most vulnerable countries in relation to coastal disasters and climate change (Thao et al., 2014). In the period 1990–2018, the damage suffered by Vietnam due to storms, floods, landslides and droughts was estimated to cost a total of almost 22 billion USD, and there were more than 12,000 deaths caused by these disasters (EM-DAT, 2019). By the end of this century, the number of storms hitting Vietnam is predicted to be unchanged. However, the number of strong storms is predicted to increase (MONRE, 2016). More intense precipitations of tropical cyclones are also predicted to occur in Southeast Asia (IPCC, 2013). This expected development is causing growing concern for the future of fisheries and other industries. In addition to investigating fishers' perceptions of different environmental, economic and social factors, the dissertation also investigates how perceived challenges relate to climate change.

The main issues dealt with in this thesis are:

1. What is the economic performance of the purse seine vessels? (Paper I)
2. What is the income per month for crew members in the purse seine fishery? (Paper I)
3. What is the input-oriented relative technical efficiency of the purse seine vessels? (papers I and II)
4. Which determinants affect the technical efficiency? (papers I and II)
5. Are larger vessels becoming more efficient than smaller vessels? (Paper I)
6. Are there significant differences in the estimated results of technical efficiencies using economic versus physical measures? (Paper II)

7. How do fishers perceive the environmental, economic and social factors impacting their current and future fishing activities? (Paper III)
8. Are there significant differences in the perceptions of changes in the selected factors between fishers of different vessel groups? (Paper III)
9. Is fishers' understanding in line with scientific knowledge, and is climate change the dominating challenge of the fishery? (Paper III)

The main goal of the dissertation is to focus on the measurement of key economic indicators and technical efficiency among 52 purse seiners, while also taking social and environmental dimensions into account. Regarding the environmental goal, the dissertation attempts to provide the fishers' perceptions regarding fish abundancy (ecological dimension) and natural environmental factors affecting the fishing activity, as well as how possible changes of these factors affect coastal communities.

The aims of the paper fit within the remit of the sustainable development concept. Sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WECD, 1987). The concept shows that three goals including economic, social and environmental optimization are linked (see Figure 1).

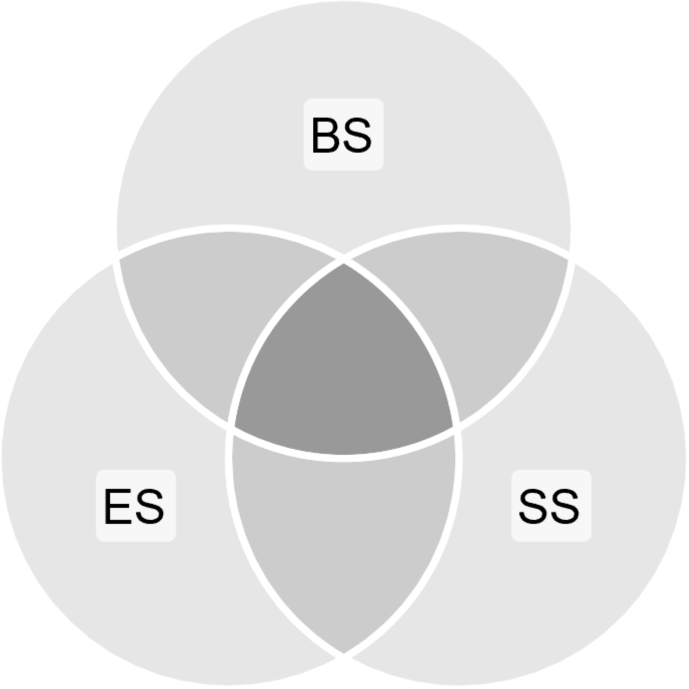

Figure 1: Sustainable development optimizes the goals across the biological and resource system (BS), the economic system (ES), and the social system (SS), as illustrated by the darker area (based on Barbier, 1987).

This dissertation adopts the three goals of a sustainable development framework for assessing the growth in fleet capacity due to governmental subsidies. In general, subsidies are known to be economically inefficient and to increase the probability of overfishing, and hence impact on the biological system (Sumaila et al., 2007). And yet, reducing excess fishing capacity is an important issue for resource sustainability, and subsidies often have a social goal.

The following section presents Vietnamese fisheries and the Nha Trang purse seine fishery. Section 3 describes the data used in the papers. Performance and perceptions within the purse seine fleet are presented in Section 4. The conclusion is described in Section 5.

2. Background

2.1. Vietnamese fisheries

2.1.1. Fleet, resources and catch

Vietnam encompasses a coastline of about 3,260 km and the exclusive economic zone (EEZ) covers more than 1 million square kilometers (FAO, 2005). More than 3.4 million people work in the fisheries sector. Vietnamese waters have about 11,000 marine species, of which approximately 130 species are of commercial interest and 30 species are regularly exploited in capture fisheries, such as tuna, round scad, mackerel, shrimp, squids, etc. The total biomass in Vietnamese ocean areas has declined by approximately 14% over a period of 10 years, from 2007 to 2018 (RIMF, 2018; Thuy, 2018).

Vietnam's marine fisheries have a long history. Fisheries development first of all took place after the economic reforms of "Doi moi" in 1986. Income from fisheries has increased, new jobs have been created and the living standards of fishing communities depending on fisheries have been improved (FAO, 2005). Subsidies to fisheries have been used as a political tool in the development of the marine capture fisheries in Vietnam, especially the offshore activity.

Since 2006, the fisheries sector, including aquaculture, has annually contributed 4% of GDP (FAO, 2005). The marine fisheries production was almost five times higher in 2016 than in 1990 and passed three million tons in 2016 (GSO, 2018).

Vietnamese fisheries are multi-species fisheries. Over the last 30 years, the national fishing fleet has increased substantially in terms of numbers and engine capacity. In 1991 the total fleet included 44,000 vessels with total engine capacity of 824,000 hp (Pomeroy et al., 2009). In 2016 the fleet included nearly 110,000 units while the total engine capacity increased by more than one thousand percent from 1991.

There is a declining trend in catch per horsepower (hp) in Vietnam's fisheries, from 0.89 tons in 1991 (Pomeroy et al., 2009) to 0.31 tons in 2016 (GSO, 2018; Vasep, 2018). Probably this reflects a reduced resource base but also technical changes in the fishing fleet.

Almost 99% of all vessels are wooden boats and 70% of the fleet operates in coastal waters with small engines (less than 90 hp). Recent steel and composite vessels constitute only 1% of the fleet.

The diverse fishing fleet makes use of about 40 different types of fishing gears. The most common fishing gears in Vietnam are different types of gillnets (used by about 36% of the fishing fleet), trawl (19%), hook and lines (16%) and purse seine (5%).

Vietnam is ranked as one of the top ten seafood exporters in the world with an export value of USD 8.3 billion in 2017. Vietnam's seafood products are exported to 165 countries. The three main markets are the EU, the U.S. and Japan, accounting for more than 60% of the total export. The EU officially issued a yellow-card warning regarding illegal, unreported and unregulated (IUU) fisheries for Vietnam's seafood export to the EU market in 2017. This market accounts for about 17% of the annual value of Vietnam's seafood exports and the warning represents a major challenge for Vietnam's seafood industry. In addition, a similar warning about IUU seafood when exporting to the U.S. market came on January 1, 2018 (Vasep, 2018). Tuna is a major product sold to these two large markets.

To combat IUU fishing, offshore fisheries, such as the tuna fisheries, are regulated (IPOL, 2018), whereas inshore fisheries are open access. The anchovy purse seine fishery studied here is an example of an inshore open-access fishery.

Fish stocks in Vietnam have declined over time (Thuy, 2018). Meanwhile, the cost of a fishing trip for offshore vessels is very high, so that fishers struggle to cover all the operating costs. Therefore, the Vietnamese government supplies subsidy programs aimed at offshore fisheries to maintain the fishing industry, as well as at-sea presence and border security. The subsidy allocations have, however, largely been based on vessel horse power or hull length, and as such are therefore also received by inshore vessels that satisfy the requirements of the subsidy programs.

According to the 1982 UN Convention on the Law of the Sea (UNCLOS), coastal states have ownership and control over resources within their exclusive economic zones (EEZ). The border between the EEZs of neighboring countries is sometimes difficult to define, creating particularly pressing issues in the South China Sea where no agreement on maritime boundaries has been settled. The fish resources in the South China Sea are shared between ten nations. However, these nations do not agree on how to share the area. Therefore, Vietnam's government encourages fishing vessels to utilize the disputed area. Hence, one motivation for the subsidies is to promote offshore vessels and by doing so increase the Vietnamese presence in disputed areas and protect the national sovereignty of Vietnam. However, the South China Sea resources are threatened, and overfishing has become a greater issue because of subsidies motivated by national goals (Long and Flaaten, 2011; Pham et al., 2021)

2.1.2. Fisheries regulations

Vessel owners have to register the technical characteristics of their fishing vessels at the Fisheries Department to obtain fishing vessel certifications. They also have to register fishing vocations, areas and the home port to get fishing licenses.

According to the 2017 Fisheries Law, effective from January 1 2019, organizations and individuals using commercial fishing vessels with a maximum length of at least 6 meters for engaging in fishing, shall have commercial fishing licenses. Previously, Vietnamese fisheries were administered based on horse power, and vessels with engines larger than 90 hp were considered offshore vessels. However, since 2019 Vietnamese fisheries have been categorized on the basis of hull length. According to the recent regulations (2017 Fisheries Law), vessels with a hull length greater than 15 m are considered offshore vessels and must submit to a stricter governmental monitoring regime. These offshore vessels have to be equipped with satellite positioning equipment, and also record and submit reports and fishing logbooks according to instructions provided by the Ministry of Agriculture and Rural Development. Vessel subsidies are now based on hull length instead of horse power, regardless of whether they actually operate offshore or inshore.

In order to combat the IUU fishing and because of the yellow card from the European Commission, monitoring, control and surveillance of fishing activities by the offshore fleet has now become more strict, and vessels will be fined heavily if fishing in foreign waters. In addition, marine protected areas (MPAs) are increasingly established to protect and conserve fish stocks. Vietnam has established MPAs in Hon Mun (in Khanh Hoa province), Van Phong Bay (in Ninh Hoa), Cu Lao Cham (in Quang Nam province), Phu Quoc (in Kien Giang) and Con Dao (in Ba Ria, Vung Tau) (Pomeroy et al., 2009). The monitoring, control and surveillance in relation to these area restrictions is regularly carried out by the patrol forces. All these factors are implemented with the goal to help Vietnam achieve responsible and sustainable fisheries in the future.

2.1.3. Subsidies of Vietnamese fisheries

In the Agreement on Subsidies and Countervailing Measures of the World Trade Organization (WTO), subsidies are defined as a financial support by a government that confers a benefit to firms or individuals. More specifically, subsidies are defined as direct or potentially direct transfers of funds from governments to firms or individuals (e.g., grants, loans, loan guarantees, equity infusions), government revenue foregone (e.g., tax waivers or deferrals), government support for prices and incomes, and government provision of goods and services, other than infrastructure, at less than market price (Schrank, 2003). Subsidies of public goods and services, such as education, enhance the supply of skilled labor. Governments also provide financial support to industries in order to obtain environmental goals and to ensure that industries behave in an environmentally friendly manner (Schrank, 2003). Political aims also motivate subsidies, such as bolstering national sovereignty in disputed border areas (for example, subsidizing the offshore fleet in Vietnam). In general, governmental subsidies affect national and local labor markets. This means that the subsidized industries become more attractive in the labor market.

A subsidy policy can be defined as an economic policy tool designed to change the prices faced by agents in the fisheries sector or to change the relative wealth of the participants. Implementation of a subsidy policy in fisheries will first influence the economic dimension. The economic effects will then lead to environmental and social effects. The impact level of the economic dimension will depend on the types of management and the status of the fish stocks (OECD, 2006)

According to Sumaila et al. (2010), there are three types of subsidies used in fisheries: capacity-enhancing, beneficial and ambiguous subsidies. Capacity-enhancing subsidies are defined as subsidy programs that lead to disinvestment in natural capital assets such that fishing capacity develops to a point where resource overexploitation makes it impossible to achieve maximum sustainable long-term benefits. The impact of these subsidies is the enhancement of overcapacity and overfishing, and results in the depletion of fish stocks. Capacity-enhancing subsidies are harmful subsidies. Fuel subsidies, and boat construction, renewal and modernization programs are classic examples of this type of subsidy.

Beneficial subsidies are subsidies that lead to investment in natural capital assets. Subsidies for fisheries management programs and services, fishery research and development, and MPAs fall into this category. These subsidies potentially enhance the growth of fish stocks through the conservation and monitoring of catch rates through control and surveillance measures.

Ambiguous subsidies are defined as programs whose impacts are undetermined. In this case, they may lead to either investment or disinvestment in the fish resource. These subsidy programs can lead to positive impacts, such as resource enhancement programs, or to negative impacts, such as resource overexploitation. Subsidies in this category include fisher assistance programs, vessel buyback programs and rural fisher community development programs.

When government implements cost-reducing subsidies without any other regulations, the fishing effort will increase. Short-run subsidies may increase profits before the fishing effort is increased accordingly and a normal profit is obtained (Flaaten and Wallis, 2000; OECD, 2006). The long-term effects of cost-reducing subsidies are that the fish stock will be affected negatively by increased fishing effort (Flaaten and Wallis, 2000; OECD, 2006).

Since the mid-1990s, the Vietnamese government has made strenuous efforts to develop its offshore fisheries. The development policy of 1997 included two broad objectives: First, to further expand marine fish production for domestic consumption and for export; and secondly to reduce the pressure on coastal fisheries resources, which had shown signs of full exploitation and even severe overfishing in some areas (FAO, 2005).

In 2005, there were two new major development goals for Vietnamese offshore fisheries: (1) *to ensure sustainable and efficient offshore fisheries, while maintaining both marine ecosystem functions and harmonious relationships with coastal fisheries and contributing to the protection of the sovereignty of the territorial waters and the national security of Vietnam* and (2) *to enhance income, create new occupations and improve the living standards of fishing communities that depend on offshore fisheries* (FAO, 2005).

In order to achieve the 1997 and 2005 development goals, programs to encourage the growth of underdeveloped offshore fisheries (such as infant fisheries) were supported. Already in 1997 Vietnam introduced an investment program for offshore vessels, and this was followed up with the introduction of capacity-enhancing fuel cost compensation subsidies in 2008, along with other subsidy programs in 2010, 2014 and in 2018 (described in more detail below). These subsidies have contributed to fleet expansion, increased production, enhanced fishing skills needed to compete effectively with foreign vessels, and support to overcome short-term economic difficulties as well as protect the sovereignty of territorial waters.

In 1997 the government started subsidizing loans to develop the offshore fishery, offering half the interest rates of commercial banks. According to Sumaila et al. (2010), preferential loans are categorized as capacity-enhancing subsides. The cost of the program was estimated to be about 94 million 2001 USD. However, the effectiveness of the program was constrained by lack of suitable fishing technologies, high costs and insufficient information about the offshore resources. Therefore, about 31% of 1300 vessels under the program experienced negative profit (FAO, 2005) and only 10% of the funded vessels were able to meet their obligations despite the interest rate having declined from 7% to 5.4% in 2003 (World Bank, 2005). By the end of 2001 the 1997 subsidy program was abolished.

Over the time period of 1996–2005, government subsidies for basic infrastructure in Vietnamese capture fisheries were estimated to be nearly 44 million 2005 USD (UNEP, 2009). In 2008, Vietnam's government started to subsidize fuel costs due to the increased fuel prices in 2007. This capacity-enhancing financial support was provided to all vessels on the basis of engine size, and a total of about 91 million USD was spent on such subsidies in 2008. By 2009 the subsidies were removed after an oil price decrease.

Vietnam's government also provided subsidies to support new offshore vessels in 2008 (4,232 USD per year for vessels with engines larger than 90 hp), as well as support for renewing the engines of offshore fishing vessels to achieve higher fuel-efficiency (605 USD/year for vessels ranging from 40–90 hp, and 1,088 USD/year for vessels larger than 90 hp). This subsidy program ran for three years (2008–2010).

In 2010, the government of Vietnam introduced another subsidy program for the offshore fishing industry (Decision, 2010). This program included fuel cost support, insurance subsidies, loans at favorable interest rates and other subsidy schemes, and commenced operation in 2011. The fuel cost subsidies were based on the engine size of the vessels and all vessels could be supported to a maximum of four trips per year. This fuel support appeared as a quasi-lump sum subsidy per trip. Vessels with an engine size from 90 hp to 150 hp were supported with approximately 940 USD per trip, vessels with an engine size from 150 hp to 250 hp received 1,304 USD per trip, vessels with an engine size from 250 hp to 400 hp received 2,348 USD per trip and vessels with an engine size of 400 hp or larger were supported with 3,130 USD per trip. Insurance subsidies covered 50% of the vessel insurance costs and 100% of the accident insurance costs for fishers. Other subsidy schemes included support for the purchase of long-range acoustic devices integrated with GPS, and damage compensation. To receive the fuel and insurance subsidies, vessel owners must fit the following requirements: (1) Offshore vessels (with engine of 90 hp or more) have to have gone through registration and are registered for regular operation in offshore areas; (2) vessel owners have to provide confirmation that they regularly operate in offshore waters approved by the specified authorities located in the offshore island areas, and submit logbooks for each fishing trip; and (3) the vessel owners need to submit a valid and complete dossier with the relevant documentation to the local fisheries management department (Circular, 2011). To get the subsidized loans, the owners had to provide the collateral for the banks.

The government also provided other support for developing Vietnamese fisheries. For example, from 2006 to 2010, the government supplied about 151 million USD for a fishing port and storm shelter center program. For fisheries information management, the Vietnamese government provided approximately 26.5 million USD in the time period of 2009–2012. From 2005 to 2015, financial support for fishing ports, landing sites, and fish markets were estimated to be nearly 169 million USD (UNEP, 2009).

In 2014, the Vietnamese government introduced a new subsidy program, which replaced the 2010 subsidy program. Most of the insurance costs, including vessel and crew insurance costs, were covered by the government in 2016. In addition, preferential loans with low interest rates were issued to finance and improve the vessels, and subsidized loans were given to cover the expenditure of fishing (Decree, 2014). Most of the insurance costs were also covered by subsidies and by building new vessels with engines between 400 and 800 hp, loans up to 90% of the vessel value were provided at an average annual interest rate of 2%. Fishers also received fuel support covering a maximum of ten trips each year. After four years, some subsidy programs were amended and replaced by a new program, which caused some reductions in the total subsidies (Decision, 2018).

In general, Vietnamese fisheries receive both harmful and beneficial subsidies. Capacity-enhancing subsidies (harmful) account for about 60% of total subsidies in Vietnamese fisheries (Harper and Sumaila, 2019). They include fuel subsidies and support for boat construction, renewal and modernization programs, tax exemptions, insurance cost, fishing ports, landing sites, fish markets, storm shelters, and basic infrastructure. Beneficial subsidies make up about 40% of total subsidies in Vietnamese fisheries (Harper and Sumaila, 2019). Fisheries management, establishing and enforcing MPAs and research and development are considered beneficial subsidies promoting Vietnamese sustainable fisheries.

Since the mid-1990s, purse seiners with engines larger than 90 hp located in Nha Trang have received subsidies aimed at developing the offshore fishery. Hence, in relation to our data set, the government in 2016 covered most of the insurance costs, including vessel and crew insurance costs. In addition, preferential loans with low interest rates were issued to finance new vessels (Decree, 2014). Most fishers have recently improved their vessels and invested in new and larger engines to enhance fishing efficiency. Consequently, since 2010 the engine capacity has increased by almost 170% despite the number of vessels having remained quite stable (130 vessels, decreased by 3.7%). Average horsepower (hp) and hull length of the Nha Trang purse seine fleet was 303 hp and 16.05 meters, respectively, in 2016.

In this dissertation, we did not collect subsidy data for the 52 vessels operating in the Nha Trang purse seine fishery, only total revenue and total cost of each vessel. Total cost includes variable (fuel cost and other variable costs) and fixed cost (the sum of maintenance and repair costs, in addition to insurance, depreciation of the vessel and other equipment, annual repayment and interest on loans). The key economic indicators for this fishery are provided in the first paper. The economic data are used to measure the technical efficiency of the fishing fleet and the excess level of inputs used (Paper I). Along with the economic data, physical data were also collected. Therefore, the average physically and economically based technical efficiencies are measured and compared using the physical and economic measures (in Paper II).

Moreover, the technical characteristics of vessels and the socio-economic characteristics of fishers are utilized to determine factors affecting different measures of technical efficiency (Papers I & II).

In general, subsidies might lead to an economically inefficient industry and an increase in the probability of fish stocks being exploited beyond biological limits (Sumaila et al., 2007). However, some types of governmental support (such as training fishers, providing information on the state of fish stocks, weather forecasts, rescue and life-saving activities in high seas) may contribute to reducing fleet capacity and effort expansion, as compared to subsidies involving financial support.

2.2. The Nha Trang purse seine fishery

Purse seine fishing commenced in the north of Vietnam in 1959 and in the south in 1975. Today purse seining dominates in 28 out of the 58 provinces of Vietnam, and the number of vessels counts more than 6,000 units, or about 5% of the total fleet. Purse seining has greatly contributed to economic development and brought jobs for thousands of coastal people in Vietnam.

Purse seine is a popular fishing gear used all over the world. The purse seine gear operates by setting up a wall of nets in the water, surrounding an area and then hauling to the vessel side. Today, most purse seiners in Vietnam are equipped with lights to attract fish, and echo-sounders for finding fish. When schools of fish gather under light sources, the net is set to encircle them.

Khanh Hoa is a coastal province in the southern part of Vietnam, on the border to the South China Sea in the east, Dac Lac and Lam Dong provinces in the west, Ninh Thuan province in the south, and in the north Phu Yen province. Khanh Hoa encompasses nearly 5,200 km^2 with a coastline of 520 km and more than 200 islands. The marine resources are diversified with more than 600 fish species, of which 50 species have a high economic value. About 31,500 people work in the fishing sector in this province. Within the province, the city of Nha Trang has the largest number of vessels, with more than 2,500 units and total earnings of nearly 86 million USD in 2015 (DECAFIREP, 2016).

Nha Trang is one of the biggest cities in Khanh Hoa province. The fisheries of Nha Trang are multi-species fisheries. While offshore fisheries are largely regulated fisheries, the inshore fisheries are still open access. This creates a high pressure on coastal fish resources.

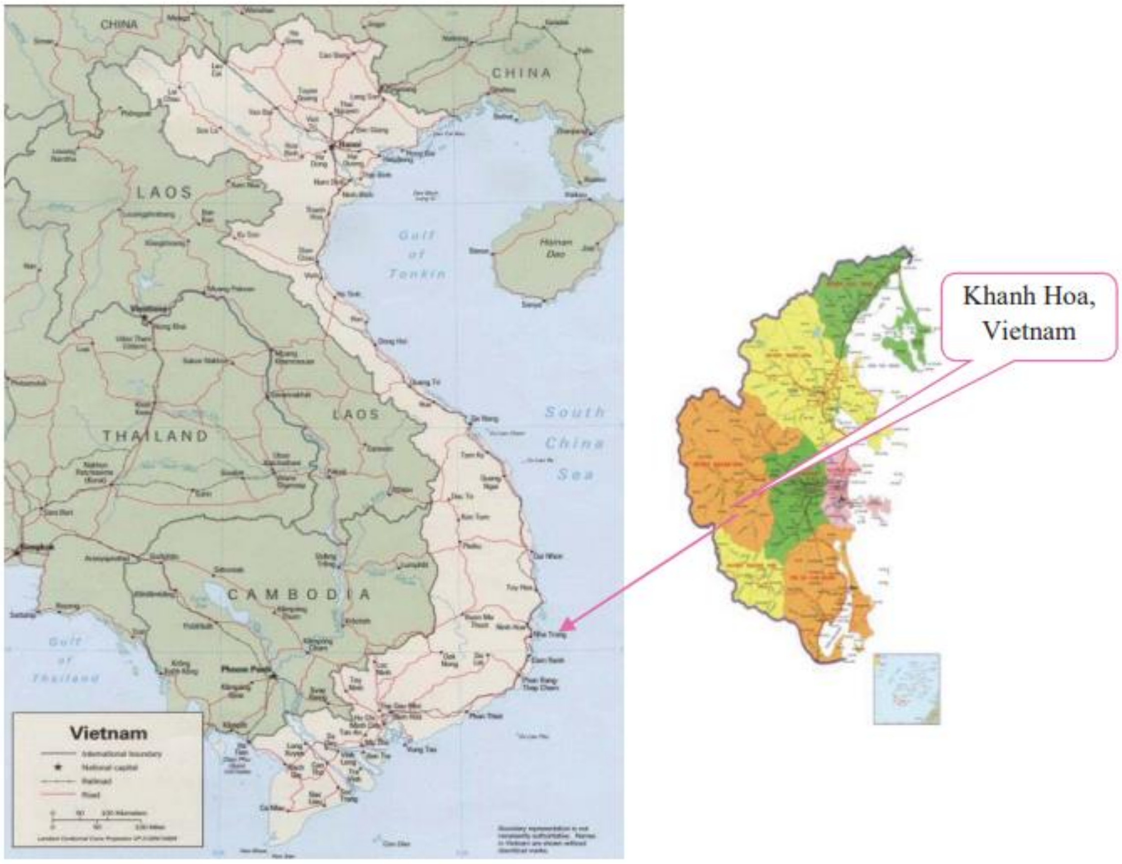

Figure 2: Khanh Hoa province, Vietnam.

The Nha Trang purse seiners usually operate all year, while the main season is from January to September. The fishery primarily targets anchovy (*Stolephorus commersonnii*) and scads (*Decapterus russelli*, *Decapterus macrosoma* Bleeker, and *Decapterus maruadsi*), with some other species (sardine (*Sardinella jussieu)*, mackerel (*Scomberomorus guttatus)* and skipjack tuna (*Katsuwonus pelamis*)) accounting for 2–3% of the total catch. The average number of crew is 14 per vessel (including the skipper). The general educational level is low, with an average of six years in school.

Fishers working in this fishery often use purse seine nets with small mesh sizes of 0.5 cm to catch anchovies. Because such fish species usually inhabit coral reefs, purse seine fishing operations could negatively impact marine ecosystems, including other fish species in these habitats. This may also lead to migration of other fish species if the coral reefs are damaged and destroyed. The Nha Trang bay is one of the main spawning and nursing areas of anchovy fish larva. Since 2002, parts of Nha Trang Bay have become a marine protected area in order to secure the recovery of ecosystems and potentially raise the income of local fishers (Ngoc et al., 2009; Xuan and Armstrong, 2019).

3. Data

This dissertation employs a data sample consisting of 52 Vietnamese purse seine vessel owners (accounting for 40% of the population of purse seine vessel owners in the area), in 2016. We developed a questionnaire in two parts: The first part was based on a survey in Thuy et al. (2013) and collected various information regarding the purse seine fishery. The questionnaire included technical and operational characteristics of each vessel, costs and earnings data, catch and price of fish information, economic and sociodemographic factors of the fishers.

The second part of the questionnaire was designed particularly for this study, covering a number of known challenges relating to how fishers perceive environmental, biological, social and technological factors affecting fishing activities, and how they evaluate changes in the studied factors, as well as climate change and adaptive strategies. The full survey was carried out from December 2016 to March 2017 at three different sites (Vinh Nguyen, Hon Ro and Vinh Truong). This was done through direct face-to-face interviews with vessel owners (and/or spouse). This dissertation also uses secondary data from a number of published papers and reports. Such data provide useful information for empirical discussion and comparison.

4. Performances and perceptions within the purse seine fleet

4.1. Literature review

Technical efficiency (TE) is developed by Farrell (1957) and measures the degree to which the vessel can produce the maximum output level at the given input level (output orientation) or use the smallest amount of inputs to produce the given output level (input orientation).

There are two approaches to measuring technical efficiency: primal and dual approaches. The primal (physical) approach estimates the technical relationship between the inputs and outputs, while the dual approach estimates the economic relationship between inputs and outputs in the form of revenue, cost or profit functions. In the dual approach, the prices of input and output and the amounts of output and input are determined in order to maximize profit, maximize revenue or minimize costs (Andersen, 2005)

Technical efficiency is often estimated based on production frontiers that compare observed production with maximal production. Two methods are commonly used to describe the efficient production frontiers and therefore measure the technical efficiency: Stochastic production frontier (SPF) and data envelopment analysis (DEA) (Charnes et al., 1978; Coelli et al., 2005). These two methods measure the distance between actual production and best-practice production. Otherwise, they are different, with the traditional production function reflecting as average production function (Andersen, 2005).

Both DEA and SPF methods have their advantages and disadvantages. The advantage of SPF is to include the inherent stochasticity because of data used when estimating technical efficiency. In addition, when using the SPF method, the results are also evaluated based on the statistical tests. Otherwise, SPF has to define specific functional forms for the production function and is only applied for the single output. DEA avoids the two disadvantages of SPF as it does not require the functional forms and can include the multi-outputs for the analysis. However, DEA does not deal with stochasticity, and all deviations from the production frontier are considered to be due to pure inefficiencies and not noise (Tingley et al., 2005).

DEA is a technique using mathematical programming to find the frontier that envelops the data observed and thus reflects the best practice. The relative efficiency of each observation is then measured relative to this frontier, as observations on the frontier are considered fully efficient. The technique has been used to analyze the technical efficiency in many different industries. Besides fisheries (Andersen, 2005; Castilla-Espino et al., 2006), examples include schools (Chakraborty et al., 2001; Waldo, 2007), banks (Favero and Papi, 1995; Le, 2018; Miller and Noulas, 1996; Sathye, 2005; Sherman and Gold, 1985) and farms (Long et al., 2020; Thap et al., 2016) .

The study of efficiency in fisheries, as in many other industries, has largely adopted an output-oriented (or primal) approach, on the assumption that fishers aim to maximize their revenue each trip (Tingley et al., 2005). Meanwhile, the input orientation has not been preferred as the output approach, where the vessels being analyzed are restricted by catch limitations in the form of quotas as well as the biological circumstances (Andersen, 2005; Pascoe et al., 2001**).** There are numerous studies on TE in fisheries. Kirkley et al. (1995) were the first to employ modern frontier techniques in measuring TE in fisheries. They have been followed by Sharma and Leung (1998), Pascoe and Coglan (2002), Fousekis and Klonaris (2003), García del Hoyo et al. (2004), Tingley et al. (2005), Jeon et al. (2006), Esmaeili (2006), Ngoc et al. (2009), Ceyhan and Gene (2014), Duy and Flaaten (2016), Digal et al. (2017). However, cost minimization has not been utilized as frequently in the fisheries literature. Examples are found in Trond Bjørndal and Gordon (2001) and Asche et al. (2008).

4.2. Methodology

As in previous fleet performance studies (Duy et al., 2012; Duy et al., 2015; Flaaten et al., 1995; Long et al., 2008; Pham et al., 2014; Whitmarsh et al., 2000), this dissertation also employs key economic indicators (gross cash flow, profit, gross profit margin and profit margin) to measure the economic performance of the purse seiners in 2016. Gross cash flow is the main economic short-term indicator. Positive gross cash flow shows what the vessel owners have earned from fishing operations after covering operating costs. Profit is the final net income after all the expenses are covered in one fishing year. If profit is negative but gross cash flow is positive, the vessels can still operate in the short run, but in the long run the vessels will exit if the situation lasts. The definition and the way of measuring economic performance used in this dissertation are in line with those applied in business economic analyses in general and in the profitability analyses of fishing vessels in Vietnam and European countries found in the articles mentioned above.

There are two approaches to measuring technical efficiency using DEA, namely output or input orientations. Output-oriented technical efficiency is measured by the observed outputs at a given level of the inputs, while an input-oriented technical efficiency is defined by the minimum amount of the observed inputs to produce a given level of outputs (Tingley et al., 2005). A major impetus to analyzing the input-oriented technical efficiency is that catches (outputs) in fisheries may be regulated at vessel level through non-transferable catch quotas (Andersen, 2005; Castilla-Espino et al., 2006). This approach gives exogenous catches (output). In contrast to this, the fishers want to maximize catch, revenue and profit at a given set of inputs when output orientation is selected. In this dissertation, input-oriented technical efficiency has been applied.

In this study, an input orientation is chosen to reduce the input as much as possible while sustaining the current catch levels. This is a reasonable assumption for the cost-minimizing behavior of fishers in developing countries, where (1) the running cost for a fishing trip is expensive but fishers' financial resources are limited since they often have difficulty accessing formal credit for operational cost because of an imperfect financial market; (2) fishers are considered as price-takers when each vessel's small landing does not impact the price of fish in the competitive market (Duy et al., 2012; Long et al., 2008). This may be relevant to the fishers' behavior which minimizes the operational cost in the fishing activities; (3) data for the analysis are based on a fishing year, not a fishing trip. When a fishing vessel goes to the fishing ground, inputs for a fishing trip are given, the catch maximizing behavior of fishermen is plausible (this means that output orientation is sensible if the data for the analysis are on a trip basis) (Tingley et al., 2005). For the whole fishing year, the cost-minimizing behavior of fishermen may be reasonable since they can easily change the number of fishing trips; (4) fisheries are traditionally characterized by a high degree of stochasticity in catches due to factors such as stock and price fluctuations, weather and luck; therefore, catch and revenue of a fishing vessel may fluctuate greatly and be uncontrollable (Andersen, 2005). This can be relevant to minimize the cost level.

In this dissertation nonparametric DEA has been applied to estimate the technical efficiency of the 52 purse seiners. The double bootstrap DEA has been used to overcome the drawbacks of the DEA method. The double bootstrap DEA approach includes two stages: The first stage is to estimate technical efficiencies using the DEA technique, and the second is to examine the factors influencing technical efficiencies through the truncated regression models. Since values between zero and one are estimated by the input-oriented technical efficiency method, it creates a censoring problem where some censored values and some values close to zero or some values being less than one third (considered as outliers) are removed (Burgess and Wilson, 1998) when estimating the Tobit model or some ordinary least squares (OLS) regression models (McDonald, 2009). Burgess and Wilson (1998) also logged the efficiency measurement to get around issues of truncation. Therefore, performing a truncated regression with maximum likelihood avoids this boundary problem (Simar and Wilson, 2007). When estimating this truncated regression model, the dependent variable will be the inverse of the DEA efficiency estimates with the value ranging from one to infinity. Both of the above steps are estimated simultaneously with the bootstrap technique.

To test the relationships and compare the estimated technical efficiency when using deterministic versus double-bootstrap DEA, pair difference t-test, Wilcoxon signed rank test, and Spearman rank correlation are used (Bogetoft and Otto, 2010; Thap et al., 2016). The parametric test (t-test) is used to define whether there is any mean difference in efficiencies between nonparametric DEA and double DEA methods. The nonparametric test (Wilcoxon signed rank test) is used to determine whether the efficiencies provided from the nonparametric DEA are greater than those found by double bootstrap DEA (Paper I).

For Paper I, economic indicators are defined for the 52 purse seiners based on costs and earnings in 2016. Revenue, variable cost, and total fixed cost are used to estimate the input-oriented technical efficiency of each vessel. In Paper I, total fixed cost is assumed to reflect the total capital value (including vessel and fishing equipment) of one year, defined as the sum of all the fixed costs, such as maintenance and repair, insurance and fees, and depreciation. Fuel cost along with costs of lubricant, ice and food constitute the variable costs of the production process. Total revenue is the sum of revenues of the three catches: anchovy, scad and others.

In order to determine factors impacting technical efficiency amongst purse seiners in the case of single output (total revenue), vessel characteristics (for example, hull length) and socio-economic factors of fishers, such as skippers' experience, loans (financial stress) and family size, are also included in the truncated regression model. In this study, hull length is a proxy of engine size, as the two are highly correlated variables. Family size is considered a proxy for crew payment.

Paper II uses the physical and economic measures of inputs and outputs to estimate the technical efficiency of the 52 vessels through DEA technique. Input orientation is also applied in this paper. The two stages of double-bootstrap DEA procedure developed by Simar and Wilson (2007) are also applied in this case. Physical outputs are the catches of anchovy, scads and others; whereas horse power, hull length and quantity of fuel are used as the physical inputs. Correspondingly, the economic outputs are revenues of anchovy, scads and others; while total fixed cost, and variable cost are used as the economic inputs.

The selection of physical and economic variables as described above was meant to purify each model, not including economic measures in the physical model and vice versa. However, there are, in addition, some variables the two models share. Man days at sea, skippers' experience, family size, loans and interest payment on loans are common variables, affecting both the physically and economically based technical efficiencies.

R software with the rDEA package created by Simm and Besstremyannaya (2016) has been utilized in the study. The double-bootstrap DEA procedure was employed separately for each of the approaches. The median comparison test was used to consider whether there is a significant difference in the technical efficiencies between the physical and economic measures.

In Paper III a graphical method has been used to visualize the fishers' evaluation on how the different environmental, economic, technological, and social factors affect fishing activities, employing five levels of impact: *severe problem*; *problem*; *no problem*; *advantage;* and *significant advantage*. The fishers' perceptions regarding possible changes in the selected factors and how severely communities may be affected, are presented. A t-test has been applied to test for linear trends over time. Also, to know whether there are differences in the perceptions of expected changes in the selected environmental, social and economic factors over time between or within the vessel groups, an ANOVA (analysis of variance) test was performed for comparison.

4.3. Research results: a summary of the papers

Paper I investigates the economic performance and technical efficiency of 52 purse seiners in Nha Trang open-access fisheries. The findings show that an average purse seiner in 2016 made a positive profit because of low labor and fuel costs. The average monthly income per crew member working in this fishery is almost the same or higher than that of industry workers in Khanh Hoa province.

In addition, when total revenue was used as a single output, total fixed cost, and variable cost are used as the inputs, the mean technical efficiency of the Nha Trang purse seine fleet under the hypothesis of variable returns to scale is 70% (with 95% confidence interval from 0.65 to

0.76) using the double-bootstrap DEA. This implies that expected inputs could be reduced by 24–35% and still sustain the current catch levels.

Paper I also demonstrates that a physical factor (hull length), and skipper experience significantly affect vessel technical efficiency at the 5% and 10 % levels. The variation in the technical efficiency and the diversity of the Nha Trang purse seine fishing fleet are discussed in this paper. It is recognized that input-oriented technical efficiency is less used, while output-oriented technical efficiency was identified as the preferred approach in fisheries when fishers want to maximize output (revenue) per trip.

The findings of Paper II show that the average physically based technical efficiency is higher than the average economically based technical efficiency by using the double-bootstrap DEA method, and there is significant difference in technical efficiency between the physical and economic measures when performing the median comparison test. Truncated regression models present that factors such as skipper experience and interest payment significantly affect the physically based technical efficiency at the 5% level. This study concludes that physical variables are capable of capturing the essential economic differences between vessels.

Regarding Paper III, findings show that heavy waves/bad weather, storms/tropical cyclones, high temperatures, heavy rains, fish resources, fishing costs, crew access, health and limited availability of capital are factors that affect the Vietnamese purse seine fleet. The fishers' perceptions of increased temperature and declining fish stocks over time are in line with observed data. However, increasing frequencies of storms and precipitation are not observed in existing data, while the fishers claim such factors create problems for their current fishing activities.

When comparing selected factors affecting fishing activities today with the situation five years ago, some factors appear to be evaluated differently amongst the vessel size groups studied. Specifically, an analysis of variance (ANOVA) shows significant differences between the smallest and largest vessels (at a 5% significance level) in the perceptions of fish market development (prices), the suitability of boats and fishing gears, harbor conditions, security, and crew access.

Almost all the surveyed fishers expect that the frequency and severity of environmental factors, such as rainfall and temperatures, will increase, while fish stocks will decline in the future. However, climate change is not expected to be among the most important negative factors in the future. Other factors, such as cost of fishing, health conditions, fishing gears and boats, and the resource situation represent greater concerns among fishers with respect to the future of their fishing activity.

Findings of Paper III are also compared with those found in the literature. Furthermore, we discuss: 1) why the fishers' perceptions of changes in storms, floods and heavy rains are not the same as the observations; 2) why fishers with larger vessels and better equipment experience greater problems with storms and heavy rain; and 3) why almost half of the fishers in the sample do not find fish abundance represents a problem in the future. The adaptive strategies of fishers to reduce or cope with the impact of climate change are also presented.

5. Conclusion

The dissertation shows that although the average profit of the studied purse seine fleet was positive in 2016, the range varies from negative to positive, possibly reflecting fleet diversity.

The average technical efficiency of the Nha Trang purse seine fleet in 2016 is found to be relatively high in analyses performed while employing the double-bootstrap DEA technique. However, the differences in technical efficiency when applying physical versus economic measures are found to be significant. Skippers' experience and interest payments were included in both cases and found to be important factors, significantly affecting the physically based technical efficiency.

The dissertation also investigates fishers' perceptions of the negative effects of storms/cyclones, severe floods, heavy rains, high temperature, big waves and bad weather, reduced fish resources, health, crew access and limited capital availability. Moreover, this thesis shows that fishers' perceptions of increased temperature and declining fish stocks are in line with observations of historical events. Fishers worry first of all about the suitability of future fishing gears and boats, fish stock development, the cost of fishing, health issues and crew access in the future.

The dissertation suggests that Vietnamese fishery managers should collect not only physical data but also economic data when such are available. Combined data will contribute in determining the general situation of Vietnamese fisheries, and help them develop appropriate management policies for sustainable fisheries in the future.

Climate change is affecting Vietnam and it is expected to bring increased risk of natural disasters to the country in the future. Therefore, it is necessary to increase the knowledge and awareness of the fishers about the threats caused by natural disasters as well as about climate change impacts now and in the future. This may help them to prepare for a harsher climate or to have adaptive strategies to reduce or cope with the impacts of climate change in a timely fashion.

Since the data of this study was collected over a short time period in 2016, it is not possible to evaluate whether the observed differences in vessel efficiency are temporary, due to changes in the distribution pattern of the stock or other random events. It is reasonable to expect that stock changes over time could affect different fleet segments in different ways. In order to find how fleet dynamics affect technical efficiency and efficiency paths of vessels over time, more data points are needed. Hopefully, the current findings can be followed up by such studies in the future.

Capacity-enhancing subsidies have been considered as a driving factor of the depletion of the fish stocks in the disputed sea area. There are indications of inefficiency in the subsidized vessels, which suggests that unsustainable fisheries will occur in the long term if the fisheries remain open access and subsidy schemes are maintained (Duy et al., 2015; Pham et al., 2021). This issue may be important for future negotiations with neighboring countries on national EEZs and the sharing of straddling and highly migratory stocks in contested ocean areas (Pham et al., 2021). Armstrong (1994) and Long and Flaaten (2011) showed that cooperation is very profitable for all countries fishing on shared resources (Pham et al., 2021). In addition, IUU fishing needs to be monitored, controlled and surveilled. These management activities may also contribute in removing the yellow card Vietnam has received from the EU, converting the fisheries into responsible and sustainable fisheries in the future as well as avoiding conflicts between the countries in relation to shared fish stock in the South China Sea.

References

Andersen, J.L., 2005. Production Economic Models of Fisheries: Vessel and Industry Analysis. PhD, Fisheries Economics and Management Division, Food and Resource Economic Institute, The Royal Veterinary and Agricultural University (KVL), Denmark.

Armstrong, C.W., 1994. Cooperative solutions in a transboundary fishery: the Russian-Norwegian co-management of the Arcto-Norwegian cod stock. Marine Resource Economics. 9, 329-351.

Asche, F., Eggert, H., Gudmundsson, E., Hoff, A., Pascoe, S., 2008. Fisher's behaviour with individual vessel quotas—Over-capacity and potential rent: Five case studies. Marine Policy. 32, 920-927.https://doi.org/https://doi.org/10.1016/j.marpol.2008.01.007

Barbier, E.B., 1987. The Concept of Sustainable Economic Development. Environmental Conservation. 14, 101-110.

Bogetoft, P., Otto, L., 2010. Benchmaking with DEA, SFA, and R. Springer Science and Business Media, New York, USA.

Burgess, J.F., Wilson, P.W., 1998. Variation in inefficiency among Us hospitals. INFOR: Information Systems and Operational Research. 36, 84-102.https://doi.org/10.1080/03155986.1998.11732348

Castilla-Espino, D., Ordaz, F.G., Sharp, B.M.H., 2006. Efficiency and capacity of fully exploited fisheries managed using vessel catch limits combined with effort restrictions. In IIFET 2006 Portsmouth Proceedings., Corvallis, Oregon, USA. https://ir.library.oregonstate.edu/concern/conference_proceedings_or_journals/9w032417v

Ceyhan, V., Gene, H., 2014. Productive efficiency of commercial fishing: Evidence from the Samsun province of Black Sea, Turkey. Turkish Journal of Fisheries and Aquatic Sciences. 14, 309-320.https://doi.org/10.4194/1303-2712-v14_2_02

Chakraborty, K., Biswas, B., Lewis, W.C., 2001. Measurement of technical efficiency in public education: A stochastic and nonstochastic production function approach. Southern Economic Journal. 67, 889-905.

Charnes, A., Cooper, W.W., Rhodes, E., 1978. Measuring the efficiency of decision making units. European Journal of Operational Research. 2, 429-444.https://doi.org/10.1016/0377-2217(78)90138-8

Circular, 2011. Guiding the Implementation of Decision 48/2010/QĐ-TTg of Vietnam's Prime Minister on July 13, 2010 on Some Policies Encouraging and Supporting for Fishing, Aquaculture and Fisheries Service on Offshore Sea Areas. Joint Circular 11/2011/TTLT-BNN-BQP-BTC of the Ministry of Agriculture and Rural Development, the Ministry of Defence and the Ministry of Finance on March 14, 2011. https://thuvienphapluat.vn/phap-luat/tim-van-ban.aspx?keyword=48/2010/Q%C4%90-TTg; .

Coelli, T.J., Rao, D.S.P., O'Donnell, C.J., Battese, G.E., 2005. An introduction to efficiency and productivity analysis, second ed. Springer Science and Business Media, New York.

DECAFIREP, 2010. The annual report of the number of vessels and engine power registered in 2010. Khanh Hoa's Department of Captures Fisheries and Resource Protection (DECAFIREP), Vietnam. http://snnptntkh.gov.vn/news/us/dep/news_detail.aspx?id=202001101705232099756.48&idDV=0.5.

DECAFIREP, 2016. The annual report of the number of vessels and engine power registered in 2016. Khanh Hoa's Department of Captures Fisheries and Resource Protection (DECAFIREP), Vietnam. http://snnptntkh.gov.vn/news/us/dep/news_detail.aspx?id=202001101705232099756.48&idDV=0.5.

Decision, 2010. Some Policies Encouraging and Supporting for Fishing, Aquaculture and Fisheries Service on Offshore Sea Areas (in Vietnamese). Decision 48/2010/QĐ-TTg of Vietnam's Prime Minister on July 13, 2010.

Decision, 2018. Decision 17/2018/ND-CP providing amendments to the Government's Decision 67/2014/ND-CP dated 7 July 2014 on certain fishery development policies. https://thuvienphapluat.vn/van-ban/Bo-may-hanh-chinh/Nghi-dinh-17-2018-ND-CP-sua-doi-Nghi-dinh-67-2014-ND-CP-chinh-sach-phat-trien-thuy-san-374719.aspx.

Decree, 2014. Decree 67/QD-TTg by Vietnam's Prime Minister on July, 7, 2014, on some polices related to fisheries development. https://thuvienphapluat.vn/van-ban/Bo-may-hanh-chinh/Nghi-dinh-67-2014-ND-CP-chinh-sach-phat-trien-thuy-san-238831.aspx?tab=1 (Accessed 07 January 2018).

Digal, L.N., Ramil, H.S.I., Placencia, S.G.P., Balgos, C.Q., 2017. Technical efficiency of Municipal fisherfolk in Maasim, Saranggani Province, Philippines: A stochastic frontier and data envelopment approach. Asian Fisheries Science. 30, 169−184.

Duy, N.N., Flaaten, O., Anh, N.T.K., Ngoc, Q.T.K., 2012. Open-access fishing rent and efficiency-The case of gillnet vessels in Nha Trang, Vietnam. Fisheries Research. 127-128, 98-108.https://doi.org/10.1016/j.fishres.2012.04.008

Duy, N.N., Flaaten, O., Long, L.K., 2015. Government support and profitability effects - Vietnamese offshore fisheries. Marine Policy. 61, 77-86.https://doi.org/10.1016/j.marpol.2015.07.013

Duy, N.N., Flaaten, O., 2016. Efficiency analysis of fisheries using stock proxies. Fisheries Research. 181, 102-113.https://doi.org/10.1016/j.fishres.2016.04.006

EM-DAT, 2019. Vietnam's disasters. https://data.humdata.org/dataset/emdat-country-profiles#metadata-0 (Accessed 01 July 2019).

Esmaeili, A., 2006. Technical efficiency analysis for the Iranian fishery in the Persian Gulf. ICES Journal of Marine Science. 63, 1759-1764.https://doi.org/10.1016/j.icesjms.2006.06.012

FAO, 2005. Report of the conference on the national strategy for marine fisheries management and development in Vietnam. FAO/FishCode Review No16, Food and Agricultural Organization of the United Nations, Rome, Italy.

Farrell, M.J., 1957. The measurement of productive efficiency. Journal of the Royal Statistical Society Series A (General). 120, 253-290.https://doi.org/10.2307/2343100

Favero, C.A., Papi, L., 1995. Technical efficiency and scale efficiency in the Italian banking sector: a non-parametric approach. Applied Economics. 27, 385-395.https://doi.org/10.1080/00036849500000123

Flaaten, O., Heen, K., Salvanes, K.G., 1995. The invisible resource rent in limited entry and quota managed fisheries: The case of Norwegian purse seine fisheries. Marine Resource Economics. 10, 341-356.https://doi.org/10.1086/mre.10.4.42629126

Flaaten, O., Wallis, P., 2000. Government Financial Transfers to Fishing Industries in OECD Countries. In IIFET 2000 Conference Proceedings, Corvallis, USA. https://ir.library.oregonstate.edu/concern/conference_proceedings_or_journals/xk81jm04n

Fousekis, P., Klonaris, S., 2003. Technical efficiency determinants for fisheries: a study of trammel netters in Greece. Fisheries Research. 63, 85-95.https://doi.org/https://doi.org/10.1016/S0165-7836(03)00019-5

García del Hoyo, J.J., Castilla Espino, D., Jiménez Toribio, R., 2004. Determination of technical efficiency of fisheries by stochastic frontier models: a case on the Gulf of Cádiz (Spain). ICES Journal of Marine Science. 61, 416-421.https://doi.org/10.1016/j.icesjms.2004.02.003

Gordon, H.S., 1954. The economic theory of a common-property resource: The fishery. The Journal of Political Economy. 62, 124-142.

GSO, 2018. Statistical yearbook of Vietnam 2018. Production of fishery in Vietnam. Statistical Publishing House, G.S.O.G., Ha Noi, Vietnam. https://www.gso.gov.vn/en/px-web/?pxid=E0651&theme=Agriculture%2C%20Forestry%20and%20Fishing (Accessed 28 October 2020).

Harper, S., Sumaila, U.R., 2019. Distributional impacts of fisheries subsidies and their reform. Case studies of Senegal and Vietnam. IIED, London.

IPCC, 2013. Climate change 2013: The physical science basis. Working group I contribution to the fifth assessment report of the intergovermental panel on climate change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPOL, 2018. Research for PECH Committee - Fisheries in Vietnam. Policy Department for Structural and Cohesion Policies, E.P., EU. https://www.europarl.europa.eu/RegData/etudes/STUD/2018/629175/IPOL_STU(2018)629175_EN.pdf.

Jeon, Y., Omar, I.H., Kuperan, K., Squires, D., Susilowati, I., 2006. Developing country fisheries and technical efficiency: the Java Sea purse seine fishery. Applied Economics. 38, 1541-1552.https://doi.org/10.1080/00036840500400525

Kirkley, J., Paul, C.J.M., Squires, D., 2002. Capacity and capacity utilization in common-pool resource industries: Definition, measurement, and a comparison of approaches. Environmental and Resource Economics. 22, 71-97.https://doi.org/10.1023/A:1015511232039

Kirkley, J., Paul, C.J.M., Squires, D., 2004. Deterministic and stochastic capacity estimation for fishery capacity reduction. Marine Resource Economics. 19, 271-294.https://doi.org/10.1086/mre.19.3.42629435

Kirkley, J.E., Squires, D., Strand, I.E., 1995. Assessing Technical Efficiency in Commercial Fisheries: The Mid-Atlantic Sea Scallop Fishery. American Journal of Agricultural Economics. 77, 686-697.https://doi.org/10.2307/1243235

Le, T.D., 2018. Bank Risk, Capitalisation and Technical Efficiency in the Vietnamese Banking System. Australasian Accounting, Business and Finance Journal. 12, 41-61.

Long, L.K., Flaaten, O., Kim Anh, N.T., 2008. Economic performance of open-access offshore fisheries-The case of Vietnamese longliners in the South China Sea. Fisheries Research. 93, 296-304.https://doi.org/10.1016/j.fishres.2008.05.013

Long, L.K., Flaaten, O., 2011. A Stackelberg analysis of the potential for cooperation in straddling stock fisheries. Marine Resource Economics. 26, 119-139.

Long, L.K., Van Thap, L., Hoai, N.T., Pham, T.T.T., 2020. Data envelopment analysis for analyzing technical efficiency in aquaculture: The bootstrap methods. Aquaculture Economics and Management. 24, 1-25.https://doi.org/10.1080/13657305.2019.1710876

McDonald, J., 2009. Using least squares and tobit in second stage DEA efficiency analyses. European Journal of Operational Research. 197, 792-798.https://doi.org/https://doi.org/10.1016/j.ejor.2008.07.039

Miller, S.M., Noulas, A.G., 1996. The technical efficiency of large bank production. Journal of Banking & Finance. 20, 495-509.https://doi.org/https://doi.org/10.1016/0378-4266(95)00017-8

MONRE, 2016. Climate change and sea level rise scenarios for Vietnam (Kịch bản biến đổi khí hậu và nước biển dâng cho Việt Nam). In Vietnamese. Natural Resouces, Environment and Cartography (NARENCA), Ha Noi, Vietnam. https://vihema.gov.vn/wp-content/uploads/2015/12/03.-Tom-tat-Kich-ban-BDKH-va-NBD-cho-VN_2016_Tieng-Viet.pdf.

Ngoc, Q.T.K., Flaaten, O., Anh, N.T.K., 2009. Efficiency of fishing vessels affected by a marine protected area – The case of small-scale trawlers and the marine protected area in Nha Trang Bay, Vietnam, in: Moksness, E., Dahl, E., Josianne, S. (Eds.), Integrated Coastal Zone Management. Wiley-Blackwell., Norway, pp. 189-206.

OECD. 2006. Financial support to fisheries. Implications for sustainable fisheries. Organisation for Economic Co-operation and Development (OECD), Paris.

Pascoe, S., Andersen, J.L., de Wilde, J.-W., 2001. The impact of management regulation on the technical efficiency of vessels in the Dutch beam trawl fishery. European Review of Agricultural Economics. 28, 187-206.

Pascoe, S., Coglan, L., 2002. The Contribution of Unmeasurable Inputs to Fisheries Production: An Analysis of Technical Efficiency of Fishing Vessels in the English Channel. American Journal of Agricultural Economics. 84, 585-597.

Pascoe, S., Tingley, D., 2016. Capacity and technical efficiency estimation in fisheries: Parametric and non-parametric techniques, in: Weintraub, A., Romero, C., Bjørndal, T., Epstein, R. (Eds.), International Series in Operations Research and Management Science. Springer., New York, pp. 273-294.

Pham, T.D.T., Huang, H.W., Chuang, C.T., 2014. Finding a balance between economic performance and capacity efficiency for sustainable fisheries: Case of the Da Nang gillnet fishery, Vietnam. Marine Policy. 44, 287-294.https://doi.org/10.1016/j.marpol.2013.09.021

Pham, T.T.T., Flaaten, O., Nguyen, L.T., Vu, N.K., 2021. Subsidies—Help or Hurt? A Study from Vietnamese Fisheries. Marine resource economics. 36, 369-387.https://doi.org/10.1086/715358

Pomeroy, R., Thi Nguyen, K.A., Thong, H.X., 2009. Small-scale marine fisheries policy in Vietnam. Marine Policy. 33, 419-428.https://doi.org/https://doi.org/10.1016/j.marpol.2008.10.001

RIMF, 2018. The result of the survey on marine resources in Vietnam 2011-2015. Research Institute for Marine Fisheries (RIMF), Vietnam. http://www.rimf.org.vn/bantin/chitiet/bao-cao-ket-qua-%C4%91ieu-tra-nguon-loi-hai-san-bien-viet-nam-giai-%C4%91oan-2011-2015 (Accessed 05 December 2021).

Sathye, M., 2005. Technical Efficiency of Large Bank Production in Asia and the Pacific. Multinational Finance Journal. 9, 1-22.https://doi.org/https://ssrn.com/abstract=2625078

Schrank, W.E., 2003. Introducing fisheries subsidies. FAO Fisheries Technical Paper No 437, FAO, Rome.

Sharma, K.R., Leung, P., 1998. Technical efficiency of the longline fishery in Hawaii: an application of a stochastic production frontier. Marine Resource Economics. 13, 259-274.https://doi.org/10.1086/mre.13.4.42629241

Sherman, H.D., Gold, F., 1985. Bank branch operating efficiency: Evaluation with Data Envelopment Analysis. Journal of Banking & Finance. 9, 297-315.https://doi.org/https://doi.org/10.1016/0378-4266(85)90025-1

Simar, L., Wilson, P.W., 2007. Estimation and inference in two-stage, semi-parametric models of production processes. Journal of Econometrics. 136, 31-64.https://doi.org/10.1016/j.jeconom.2005.07.009

Simm, J., Besstremyannaya, G., 2016. Package 'rDEA'. https://cran.r-project.org/web/packages/rDEA/rDEA.pdf (Accessed 11 December 2017).

Sumaila, U.R., Khan, A., Watson, R., Munro, G., Zeller, D., Baron, N., Pauly, D., 2007. The World Trade Organization and global fisheries sustainability. Fisheries Research. 88, 1-4.https://doi.org/10.1016/j.fishres.2007.08.017

Sumaila, U.R., Khan, A.S., Dyck, A.J., Watson, R., Munro, G., Tydemers, P., Pauly, D., 2010. A bottom-up re-estimation of global fisheries subsidies. Journal of Bioeconomics. 12, 201-225.https://doi.org/10.1007/s10818-010-9091-8

Thao, N.D., Takagi, H., Esteban, M., 2014. Coastal disasters and Climate change in Vietnam: Engineering and planning perspectives. Elsevier, London and US.

Thap, L.V., Long, L.K., Hoai, N.T., 2016. Analysis of technical efficiency of intensive white-leg shrimp farming in Ninh Thuan, Vietnam: An application of the double-bootstrap data envelopment analysis. In IIFET 2016 Scotland Conference Proceedings, Corvallis, USA. https://ir.library.oregonstate.edu/concern/conference_proceedings_or_journals/q524jq64g

Thuy, L.T.N., 2018. Vietnam fisheries towards a more sustainable and responsible development. Faculty of Management, University of Tampere, University of Tampere, Finland.

Thuy, P.T.T., Flaaten, O., Anh, N.T.K., 2013. Remuneration systems and economic performance: Theory and Vietnamese small-scale purse seine fisheries. Marine Resource Economics. 28, 19-41.https://doi.org/10.5950/0738-1360-28.1.19

Tingley, D., Pascoe, S., Coglan, L., 2005. Factors affecting technical efficiency in fisheries: stochastic production frontier versus data envelopment analysis approaches. Fisheries Research. 73, 363-376.https://doi.org/https://doi.org/10.1016/j.fishres.2005.01.008

Trond Bjørndal, Gordon, D.V., 2001. The Economic Structure of Harvesting for Three Vessel Types in the Norwegian Spring-Spawning Herring Fishery. Marine Resource Economics. 15, 281-292.

UNEP, V.W., 2009. Fisheries Subsidies, Suply Chain and Certification in Vietnam. Final Summary Report in Vietnam. Hanoi, Vietnam.

Vasep. 2018. Whitebook on combating IUU fishing in Vietnam. Vietnam Association of Seafood Exporters and Producers, Vietnam.

Waldo, S., 2007. On the use of student data in efficiency analysis—Technical efficiency in Swedish upper secondary school. Economics of Education Review. 26, 173-185.https://doi.org/https://doi.org/10.1016/j.econedurev.2005.06.005

WECD, 1987. Our Common Future. and, T.W.C.o.E., Development, Oxford: Oxford University Press.

Whitmarsh, D., James, C., Pickering, H., Neiland, A., 2000. The profitability of marine commercial fisheries: a review of economic information needs with particular reference to the UK. Marine Policy. 24, 257-263.https://doi.org/10.1016/S0308-597X(00)00002-6

World Bank, 2005. Vietnamese Fisheries and Aquaculture Sector Study. Bank, W., Washington, DC: World Bank. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/955841468778172387/fisheries-and-aquaculture-sector-study (Accessed on 16, July, 2021).

Xuan, B.B., Armstrong, C.W., 2019. Trading Off Tourism for Fisheries. Environmental and Resource Economics. 73, 697-716.https://doi.org/10.1007/s10640-018-0281-5

PART 2: PAPERS

Paper I:

Cao Thi Hong Nga, Arne Eide, Claire W. Armstrong, Le Kim Long

Economic performance and technical efficiency in a Vietnamese purse seine fishery

Manuscript

Economic performance and technical efficiency in a Vietnamese purse seine fishery

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Abstract

This study identifies differences in vessel efficiency amongst purse seiners in a Vietnamese fishery. Deterministic data envelopment analysis (DEA) was used to assess the relative technical efficiency of each vessel, and double bootstrap DEA was adopted to overcome some of the drawbacks of nonparametric DEA. The study was based on a survey of costs and earnings from 52 purse seiners in 2016, revealing an average vessel profit margin of 11 %. By adopting double bootstrap DEA while assuming variable returns to scale, mean technical efficiency was found to be 0.7 (with 95 % confidence interval from 0.65 to 0.76). This indicates that to sustain the current catch levels, expected inputs should be reduced by 24–35 %. The study shows that both vessel size and fishing experience are factors affecting the technical efficiency.

Keywords: Economic performance, Technical efficiency, DEA, Double bootstrap DEA, purse seining.

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1. Introduction

It is well established that an open access fishery eventually leads to dissipation of natural resource rent and attracts fishing effort beyond any equilibrium level where such rent may be collected (Gordon, 1954). Scott Gordon's seminal paper also shows that given his biological assumptions, only the most cost-efficient vessels, in the long run, will remain in the open-access fishery, all earning a normal profit. Hence, the standard theory suggests the fleet will, in the long term, develop towards homogeneity. However, quasi rent and intra marginal rent may exist in most fisheries due to natural and market fluctuations, leading to fleet diversity. This paper presents a study of a Vietnamese fishing fleet operating in a de facto open-access situation, to assess efficiency and diversity. The fleet has become more dominated by large units over recent years. This development is believed partly to be a consequence of governmental subsidies prioritising larger vessels and engines, despite it in principle being an open access fishery. The fishery primarily targets anchovy, *Stolephorus commersonnii* Lacepède, 1803, scads, *Decapterus russelli* (Rüppell, 1830), *Decapterus macrosoma* Bleeker, 1851 and *Decapterus maruadsi* (Temminck and Schlegel, 1843), with some bycatch of other species (sardine, *Sardinella jussieu* (Lacepède, 1803), mackerel, *Scomberomorus guttatus* (Bloch and Schneider, 1801) and skipjack tuna, *Katsuwonus pelamis* (Linnaeus, 1758)) accounting for 2–3 % of the total catch. The fleet sails out from the port of Nha Trang (in the southern part of Vietnam), a port including more than 2500 fishing vessels with total earnings of nearly 86 million USD in 2015 (DEAGRUD, 2016).

Vietnam is a major fishing nation with annual growth in landings of almost 6 % since the early 1990s (GSO, 2018a). The fishing industry (including aquaculture) contributes about 4 % of national GDP each year (FAO, 2005). However, catch per horsepower (hp) shows a declining trend, from 0.89 ton.hp^{-1} in 1991 (Pomeroy et al., 2009) to 0.31 ton.hp^{-1} in 2016 (GSO, 2018a; Vasep, 2018). This reduction may reflect a decline in the resource base and technical changes in the fleet. The average vessel has become larger, and the average engine size has increased by a factor of three from 2009 to 2016 according to DECAFIREP (2010 and 2016). Less is known about the changes in the resource base, as biological information is characteristically data poor in Vietnam. However, the general declining trend in catch per unit of horsepower also seems to be representative for the investigated fishery.

The aim of this study, therefore, was to investigate the economic performance of the vessels participating in the Nha Trang purse seine fishery. A sample of 52 of a total of 130 vessels in the purse seine fleet was included in the study. Moreover, data envelopment analysis (DEA) was used to measure the technical efficiency (TE) of the purse seiners, and the bootstrap technique was applied to overcome some of the limitations related to the DEA method. The double bootstrap DEA method, developed by Simar and Wilson (2007), was employed to provide the bias-corrected DEA efficiency estimates, as well as statistical inference of the factors affecting TE.

The aim was to further compare and analyse the findings based on known vessel differences, socio-economic differences and the findings of other similar studies. Can observed physical vessel differences explain possible variation in TE, or are socio-economic differences within the different crews more likely to provide an explanation? In addition, how do the findings compare with other studies from other fisheries? For example, are open-access fisheries more exposed to large differences in TE than regulated fisheries are?

2. Materials and methods

Primary data were obtained from a survey including 52 purse seine owners selected from the 130 purse seiners registered at Khanh Hoa Department of Capture Fisheries and Resources Protection in Nha Trang, in 2016 (DECAFIREP, 2016). The 52 vessels were selected based on hull length and horsepower, to ensure average values in the sample similar to the total population (Table 1).

Table 1. Key measures used to qualify the sample as representative for the purse seiners in 2016.

Variable	Sample size = 52		Population size = 130		t-test statistics
	Mean	S.D.	Mean	S.D.	
Hull length	16.05	2.60	15.94	2.86	0.30
Engine power	303.10	163.27	300.35	173.29	0.12

S.D.: standard deviation

Additional face-to-face interviews were conducted in 2016 with vessel owners (and/or their spouses) to collect information on technical and operational characteristics, costs and earnings of the purse seine fleet, and various economic and social factors regarding the fishers. The list of registered fishing vessels in Khanh Hoa in 2016 and other relevant information was also collected for this study.

This study employs key economic indicators (gross cash flow, profit, gross profit margin and profit margin) to measure the economic performance of the purse seiners in 2016. Input-oriented TE studies are rather rare, as fisheries studies focus primarily on measuring output-oriented TE (Andersen, 2005; Castilla-Espino et al., 2006). In this study, an input orientation is chosen to reduce the input as much as possible while sustaining the current catch levels. This is a reasonable assumption for the cost-minimising behaviour of fishers in developing countries, for four reasons. (1) The running cost for a fishing trip is expensive but the financial resources of fishers are limited since they often have difficulty in gaining access to formal credit mechanisms for operational costs because of an imperfect financial market. (2) Fishers are considered as price takers when each vessel's small landing does not impact the price of fish in the competitive market (Long et al., 2008; Duy et al., 2012). This may be relevant to the fishers' behaviour that minimises the operational cost in the fishing activities. (3) Data for the analysis are based on the fishing year, not a fishing trip. When a fishing vessel goes to the fishing ground, inputs for a fishing trip are given, and the catch-maximising behaviour of fishermen is plausible (it means that an output orientation is sensible if the data for the analysis are on a trip basis) (Tingley et al., 2005). For the whole fishing year, the cost-minimising behaviour of fishermen may be reasonable since they can easily change the number of fishing trips. (4) Fisheries are traditionally characterised by a high degree of stochasticity in catches due to factors such as stock and price fluctuations, weather and luck; therefore, catch and revenue of a fishing vessel may fluctuate wildly and be uncontrollable (Andersen, 2005). This can be relevant to minimise the cost level.

An input-oriented TE assumes a given level of output produced by the minimum amount of input factors. We assume that first-hand fish prices and the prices of all inputs are the same for all vessels. Differences in cost efficiency between vessels reflect the differences in the input-oriented TE (Pascoe et al., 2003), such as the skill of the crew and skipper (Squires and Kirkley, 1999) or the technical characteristics of the vessel (Pascoe and Coglan, 2002).

A TE analysis is based on the following scheme:

Let x_j be the quantity of an input factor in the production of harvest (u_j) by vessel j. z_j is the intensity variable that is used to define the linear combination of the peers of the j^{th} vessel. j indicates the total number of vessels (52 in this study), and the DEA methodology is summarised by

$TE_j(u, x) = \min \theta_j$

subject to

$$\begin{aligned} u_j &\leq \textstyle\sum_{j=1}^{J} z_j\, u_j \\ \theta_j x_j &\geq \textstyle\sum_{j=1}^{J} z_j x_j \\ z_j \geq 0, j = 1,2,\ldots,J;\ &\textstyle\sum_{j=1}^{J} z_j = 1. \end{aligned} \tag{1}$$

$TE_j(u, x)$ represents the TE as a function of output u and input x. θ_j is the input-oriented TE with a value between 0 and 1 (Castilla-Espino et al., 2006). The convex constraint, $\sum_{j=1}^{J} z_j = 1$, shows that the production technology exhibits variable returns to scale (VRS) (Coelli et al., 2005).

The difference in TE amongst purse seiners is described by:

$$\widehat{\delta_J} = \beta Z_j + \varepsilon_j \geq 1. \tag{2}$$

In equation (2) the dependent variable is the TE score, $\widehat{\delta_J} = \frac{1}{\widehat{\theta_J}}$. Z_j is a set of exogenous variables, while β_j are parameters of the model to be estimated. In this equation, ε_j is a continuous, independent and identically distributed random variable.

The DEA efficiency estimates found by the use of method (1) are sensitive to variation in sample size and number of variables used in the DEA model (Zhang and Bartels, 1998). Furthermore, the standard inference in the second-stage DEA method is statistically invalid due to the DEA TE estimates for being serially correlated (Simar and Wilson, 2007). In order to overcome the limitation of DEA, the bootstrap methodology has been applied in this study.

The bootstrap technique is considered as a way to simulate a true sampling distribution by a data generating process (DGP) from the original data set (Balcombe et al., 2008; Olson and Vu, 2009). The DEA model applied here is re-estimated with the new data set or the pseudo replicate data generated by the original data set, and this process is repeated many times to yield the empirical distributions of the estimators of the parameter of interest that give a Monte Carlo approximation of the sampling distribution and a feasible inference procedure. The DGP that provides the rationale for Simar and Wilson (2007) double bootstrap procedure is used to provide the biased corrected confidence intervals for the TE estimate in (1) and enable consistent inference within the truncated regression model explaining TE in (2). Therefore, the DEA double bootstrap technique proposed by Simar and Wilson (2007) is employed for the current study.

Since the purse seine fishery in question is a multispecies fishery, revenue was chosen as the output variable in the estimation of TE. Total fixed cost, taken as the measure of the capital value (including vessel and fishing equipment) in one year, is defined by summing all the fixed costs such as maintenance and repair, insurance and fees, including depreciation (see Table 2). Fuel cost constitutes a major part of the variable cost in the purse seine fishery. Other variable costs are the costs of lubricant, ice and food. For Nha Trang fisheries, labour payment is a share of the revenue minus variable costs per fishing trip. Hence, in this study labour cost is represented by man days at sea (number of days multiplied by the number of crew members, including skipper). However, there is a high correlation (0.87) between the variable cost and man days at sea, and therefore, man days at sea is taken out of the DEA model.

In order to explain differences in TE amongst purse seiners, the vessel characteristics and socio-economic factors of fishers are also included in equation (2) and the truncated regression model (see Table 2). In this study, hull length is a proxy of engine size, as the two are highly correlated variables. Family size is considered as a proxy for crew payment. Regarding the financial stress, some people are unable to get a loan, and thus they might be under more stress than those who are able to do so.

Table 2 shows the means and standard deviations of some core variables in the data sample of the 52 purse seiners.

Table 2. Basic statistics for variables in the sample of 52 purse seine vessels in 2016.

Variables	**Measurement unit per vessel**	**Mean**	**S.D.**	**Min**	**Max**
Inputs and output employed in the DEA model					
Total fixed cost	million VND	263.69	111.18	75.97	627.69
Variable cost	million VND	757.60	280.28	228.00	1438.50
Revenue	million VND	1755.44	790.14	450.00	3491.40
Truncated regression model					
Hull length (Z1)	meters	16.05	2.60	11.00	22.85
Skippers' experience (Z2)	years	26.81	7.16	11.00	39.00
Skippers' experience ^2 ($Z2^2$)	$years^2$	769.00	364.83	121.00	1521.00
Financial stress (Z3)	yes/no	0.40	0.49	0.00	1.00
Family size (Z4)	persons	4.98	1.36	3.00	10.00

S.D.: standard deviation

The analysis is performed using the rDEA package created by Simm and Besstremyannaya (2016) in R. The double bootstrap DEA model with L_1 = 100 interactions for the first loop and L_2 = 2000 for the second loop of Algorithm 2 was applied, as developed by Simar and Wilson (2007).

3. Results

Table 3 shows the economic indicators of the purse seine fleet in Nha Trang in 2016. In that year an average purse seiner obtained a profit of 272.11 million VND with a corresponding profit margin of 11 %.

Table 3. Statistics for economic key indicators in the sample of 52 purse seine vessels in 2016.

Criteria	Mean	S.D.	Min	Max
Gross revenue	1755.44	790.14	450.00	3491.40
Variable cost	757.60	280.28	228.00	1438.50
Fuel costs	386.21	150.70	115.20	864.00
Other variable cost	371.39	157.99	83.70	743.40
Fixed cost	129.98	85.91	2.64	354.11
Maintenance and repair	126.58	85.93	0.00	350.00
Insurance and fee	3.41	1.14	0.58	5.81
Labour cost	426.92	231.28	103.49	856.56
Gross cash flow	440.94	347.17	-135.92	1205.59
Depreciation	133.71	64.15	53.29	310.46
Interest payment on loans	35.12	53.82	0.00	220.00
Profit	272.11	284.99	-230.76	868.32
Gross profit margin	0.21	0.12	-0.19	0.39
Profit margin	0.11	0.14	-0.31	0.34
Income per crew member	28.86	12.41	7.11	50.35

Gross cash flow = gross revenue - operating cost - labour cost; Profit = gross cash flow - depreciation - interest payment on loans; Gross profit margin = gross cash flow/gross revenue; Profit margin = profit/gross revenue; S.D.: standard deviation. *Note: all the economic indicators are measured in million VND (1 million VND = 44.014 USD), except for gross profit margin and profit margin.*

Table 4 presents the input-oriented DEA results of the purse seine fleet after employing equation (1) and using the input variables presented in Table 2. An estimated TE ranging from 0.4 to 1 means that the lowest TE of this fleet is 40 %, with average TE being 0.7 based on the deterministic DEA technique under the constant returns to scale (CRS) hypothesis. The VRS figures come out somewhat above this, with an average TE of 0.78. Using the double bootstrap DEA method under the VRS hypothesis, the TE of an average vessel is 0.7. Hence, 30 % of the TE is not fully utilised, compared to the most efficient purse seiner.

Table 4. Calculated TE in the sample of 52 purse seiners, based on deterministic and double bootstrap DEA methods. TE_CRS refers to TE while assuming constant returns to scale, and TE_VRS assumes variable returns to scale. SD refers to standard deviation and CI to confidence interval.

Criteria	**Deterministic DEA**			**Double bootstrap**					
	Mean	**SD**	**Min**	**Mean**	**SD**	**Min**	**Max**	**Lower 95 % CI for mean**	**Upper 95 % CI for mean**
TE_CRS	0.70	0.17	0.40	0.66	0.16	0.37	0.95	0.63	0.70
TE_VRS	0.78	0.17	0.45	0.70	0.15	0.40	0.93	0.65	0.76

Table 4 shows the 95 % confidence intervals for mean TE of the purse seine fleet in 2016. Using the double bootstrap method, the bias-corrected TE has a 95 % confidence interval between 0.65 at the lower limit and 0.76 at the upper limit, with the width of the confidence interval equalling 0.11, under the VRS hypothesis.

To test the relationships and compare the estimated TE when using deterministic versus double bootstrap DEA, we deployed the pair difference t-test, Wilcoxon signed rank test, and Spearman rank correlation (Bogetoft and Otto, 2010; Thap et al., 2016). The parametric test (t-test) is used to define whether there is any mean difference in efficiencies between nonparametric DEA and double DEA methods. The nonparametric test (Wilcoxon signed rank test) is used to determine whether the efficiencies provided from the nonparametric DEA are greater than those found by double bootstrap DEA. To test whether there is a correlation between these two efficiency estimates, the Spearman rank correlation is also applied.

The results in Table 5 show—based on the paired t-test and the Wilcoxon signed rank test—that the TE obtained from the deterministic DEA method under both CRS and VRS are statistically significantly different and higher (levels of significance are displayed in Table 5) than those found when using the double bootstrap procedure.

Table 5. Mean comparison and correlations of TE in the sample, rankings based on Spearman and Wilcoxon signed rank test. TE_CRS refers to TE while assuming constant returns to scale, and TE_VRS assumes variable returns to scale.

	t-ratio	**Spearman rank correlation**	**Wilcoxon signed rank test (*P*-value)**
TE_CRS	13.88***	0.99***	0.000**
TE_VRS	14.82***	0.97***	0.000**

******* *significant at 1 % level* ** *significant at 5 % level*

Table 6 shows the excess use of inputs in the Nha Trang purse seine fleet in the 2016 season. The findings show that vessel owners in this industry could reduce cost in their fishing activity. The cost savings described when applying the double bootstrap technique are even larger.

Table 6. Excess use of inputs defined by differences between the actual inputs and the optimal inputs in the sample of 52 purse seiners.

Criteria	**Actual input**	**Deterministic DEA**		**Double bootstrap DEA**	
		Optimal input	Excess use of input	Optimal input	Excess use of input
Total Fixed Costs					
Mean	263.69	203.28	60.41	184.19	79.5
Sum	13711.89	-	3141.23	-	4143.08
% excess	-	-	22.91	-	30.15
Variable Cost					
Mean	757.60	593.8	163.82	536.21	221.39
Sum	39395.22	-	8518.84	-	11512.42
% excess	-	-	21.62	-	29.23

Table 7 indicates that hull length is positively related to TE within the 95 % confidence interval in the double bootstrap method. This result shows that the larger the vessel, the higher the TE. In addition, the TE increases with the skippers' experience, but at a decreasing rate, with these estimates being statistically significant at the 10 % level. Furthermore, there is a positive relationship between financial stress and TE. However, this relationship is not statistically significant.

Table 7. Determinants of TE score (the inverse of TE) estimated by the double bootstrap method.

Variables	**Coefficient**	**95 % confidence interval**		**90 % confidence interval**	
		Lower	**Upper**	**Lower**	**Upper**
Intercept	2.9903**	1.8377	6.0855	2.4372	5.7460
Hull length (Z1)	-0.0718**	-0.1595	-0.0102	-0.1514	-0.0288
Skippers' experience (Z2)	-0.0626*	-0.2094	0.0198	-0.1899	-0.0035
Skippers' experience ^2 ($Z2^2$)	0.0015**	0.0000	0.0043	0.0004	0.0039
Financial stress (Z3)	-0.0402	-0.2772	0.3102	-0.2316	0.2631
Family size (Z4)	-0.0049	-0.1832	0.0227	-0.1747	0.0029

*** significant at 5 % level   * significant at 10 % level*

4. Discussion

As pointed out in the introduction, the income of the studied purse seine fleet covered their operating costs and resulted in profits in 2016. These profits were due to the low cost of labour in Vietnam. The opportunity cost of labour is related to GDP per capita (Long et al., 2008; Pham et al., 2014). For example, in 2016, the GDP per capita in Vietnam was 2,173.27 USD, substantially lower than that of China (8,113.25 USD) and Malaysia (9,360.47 USD) (IMF, 2019). Another reason for the positive profit was that the fuel price declined in 2016 by 30 % (0.53 US\$.L^{-1}) compared to 2011 (0.79 US\$.L^{-1}). Fuel costs constituted about 52 % of total variable costs in 2016.

Moreover, the average monthly income per crew member working in this fishery in 2016 (3.59 million VND) was higher than the overall average for Khanh Hoa, which was 2.89 million VND per capita per month (GSO, 2018b). This shows that the crew members earned the opportunity cost of labour or above in this operating year (Duy et al., 2015).

The findings show that hull length had a significant and positive relationship with vessel efficiency. Another factor that had a statistically insignificant and positive impact on the TE in this study was the family size, presumably impacting payment of the crew. Skippers' fishing experience (a proxy for skipper skills) was positively correlated to TE, but at a decreasing rate. Some results are in contrast to the findings reported by Ngoc et al. (2009), where family size negatively affected the TE of the Nha Trang trawl fishery. In addition, those authors found that the skippers' fishing experience had a positive effect on TE. This factor, however, were not statistically significant (Ngoc et al., 2009). Regarding financial stress, the results of the present study were found to be different from the findings of Thap et al. (2016), showing a negative relationship between access to financial resources and efficiency in the case of intensive white-leg shrimp farming in Ninh Thuan (Vietnam). Also in the current study, this factor did not obtain statistical significance in the case of the Nha Trang purse seine fishery.

The findings presented in Table 5 indicate the correlation between TE estimated by both the deterministic and double bootstrap DEA methods. Family size (Table 7), as a proxy for payment of crew, relates positively to TE. Fishing activities are fluctuating and may require seasonal workers from other parts of the country. Such employees often require higher wages than the local labour force since the use of family members could imply a lower cost of labour. Otherwise, we do not find a statistical relationship between family size and low payment for the crew.

The TE of vessels varied due to differences in cost structures. Adopting the DEA double bootstrap method under VRS, the bias-corrected efficiency of an average vessel in the Nha

Trang purse seine fishery was 0.7. In addition, the single-year observations also revealed an excess use of inputs in the Nha Trang purse seine fleet.

The TE levels identified by the use of the nonparametric method are higher than those found by the double bootstrap method. This result corresponds to the observations of Simar and Wilson (2000), who found that the deterministic DEA method positively exaggerated the level of efficiency in their specific sample. The double bootstrap method takes into account the sampling error and provides a bias-corrected efficiency estimate from which one may suggest broad policy implications. Other factors affecting the TE include the impact of subsidies, the political arguments for subsidies, variability in weather conditions, stock sizes and distributions, and possibly market variations. Such factors were not corrected for in this study.

This study cannot confirm whether or not the purse seine fishery is characterised by overcapacity, as the crucial biological factors are unknown, and the data were collected over only one year. However, the results show that some vessels had low relative TE, even below 0.5. It is not known if these vessels were more efficient in other years, due to factors such as changes in fish distribution patterns or weather conditions. Random noise in production potentially plays a significant role in fisheries, possibly reflected in fleet diversity.

5. Conclusion

This survey of 52 purse seiners in Vietnam revealed an average vessel profit margin of 11 % in 2016. Three-quarters of the fleet experienced good earnings in spite of significant differences in TE levels measured in terms of inputs to harvest production.

Excess capacity was identified in the purse seine fleet. Excess capacity represents an economic loss and may indicate a potential threat of overfishing. If the excess capacity is kept and fully utilised, instead of producing the current fishing output with a smaller fleet (and full utilisation of the vessels), the overfishing issue could become more critical.

The study revealed that physical factors (such as hull length) affect a vessel's TE. The study also showed that TE increases at a decreasing rate based on the experience of the skipper. The purse seine fleet seems to be in a transition period, moving from one that is dominated by small vessels to one dominated by larger vessel sizes. This development is enhanced by subsidies, but it is not clear if the increased TE resulting from vessel size can be explained only by this factor.

Since the study was done over a short period in 2016, it is not possible to explain the observed differences in vessel efficiency, which could be due to biological changes. However, it is equally reasonable to expect that stock changes over time could affect the different fleet segments in different ways. Stock changes may also explain the existing fleet diversity, even though this fleet seems to develop towards less diversity over time. To determine how fleet dynamics affect TE and efficiency paths of each vessel over time, more data points are needed. Hopefully, the current investigation can be followed up by such studies in the future.

This study shows the fleet's mean TE indicates that to sustain the current catch levels, expected inputs in this fishery could be reduced by 24–35 %. The role played by subsidies is not clear from this study, but in general it is known that subsidies might lead to an economically inefficient industry and an increase in the probability that fish stocks will be exploited beyond their biological limits (Sumaila et al., 2007). Instead of financial support, other types of governmental support (such as training fishermen, providing information on the state of fish stocks, weather forecasts, rescue and life-saving activities in high seas) could contribute to reducing fleet capacity and effort expansion.

Acknowledgements

We wish to thank the Norhed project SRV-13/0010 for providing financial support for the data survey. We also are grateful for valuable input from the committee at The Arctic University of Norway.

References

Andersen, J.L., 2005. Production Economic Models of Fisheries: Vessel and Industry Analysis. PhD, Fisheries Economics and Management Division, Food and Resource Economic Institute, The Royal Veterinary and Agricultural University (KVL), Denmark.

Balcombe, K., Fraser, I., Latruffe, L., Rahman, M., Smith, L. (2008). An application of the DEA double bootstrap to examine sources of efficiency in Bangladesh rice farming. Applied Economics 40: 1919-1925.https://doi.org/10.1080/00036840600905282

Bogetoft, P., Otto, L. 2010. Benchmaking with DEA, SFA, and R. Springer Science and Business Media, New York, USA. 187-188 pp.

Castilla-Espino, D., Ordaz, F.G., Sharp, B.M.H. 2006. Efficiency and capacity of fully exploited fisheries managed using vessel catch limits combined with effort restrictions. In IIFET 2006 Portsmouth Proceedings. International Institute of Fisheries Economics and Trade (IIFET), Corvallis, Oregon, USA. https://ir.library.oregonstate.edu/concern/conference_proceedings_or_journals/9w032417v. (Accessed 30 October 2017).

Coelli, T.J., Rao, D.S.P., O'Donnell, C.J., Battese, G.E. 2005. An introduction to efficiency and productivity analysis. Springer Science and Business Media, New York. 172, 202 pp.

DEAGRUD 2016. Master plan for Khanh Hoa fishery sector during 2016-2025 and orientation for year 2035 (Quy hoạch phát triển ngành thủy sản tỉnh Khánh Hòa giai đoạn 2016-2025 và định hướng đến năm 2035). (In Vietnamese). Khanh Hoa's Department of Agriculture and Rural Development (DEAGRUD), Vietnam. 27 pp.

DECAFIREP 2010. The annual report of the number of vessels and engine power registered in 2010. Khanh Hoa's Department of Captures Fisheries and Resource Protection (DECAFIREP), Vietnam.

http://snnptntkh.gov.vn/news/us/dep/news_detail.aspx?id=2020011017052320997 56.48&idDV=0.5.

DECAFIREP 2016. The annual report of the number of vessels and engine power registered in 2016. Khanh Hoa's Department of Captures Fisheries and Resource Protection (DECAFIREP), Vietnam. http://snnptntkh.gov.vn/news/us/dep/news_detail.aspx?id=20200110170523209975 6.48&idDV=0.5.

Duy, N.N., Flaaten, O., Long, L.K. (2015). Government support and profitability effects - Vietnamese offshore fisheries. Marine Policy 61: 77-86.https://doi.org/10.1016/j.marpol.2015.07.013

Duy, N.N., Flaaten, O., Anh, N.T.K., Ngoc, Q.T.K. (2012). Open-access fishing rent and efficiency-The case of gillnet vessels in Nha Trang, Vietnam. Fisheries Research 127-128: 98-108.https://doi.org/10.1016/j.fishres.2012.04.008

FAO 2005. Report of the conference on the national strategy for marine fisheries management and development in Vietnam. FAO/FishCode Review No16, Food and Agricultural Organization of the United Nations, Rome, Italy. 34 pp.

Gordon, H.S. (1954). The economic theory of a common-property resource: The fishery. The Journal of Political Economy 62: 124-142.

GSO 2018a. Statistical yearbook of Vietnam 2018. Production of fishery in Vietnam. Statistical Publishing House, G.S.O.G., Ha Noi, Vietnam. https://www.gso.gov.vn/en/px-web/?pxid=E0651&theme=Agriculture%2C%20Forestry%20and%20Fishing. (Accessed 28 October 2020).

GSO 2018b. Statistical yearbook of Vietnam 2018. Monthly average income per capita in Khanh Hoa. Statistical Publishing House, G.S.O.G., Ha Noi, Vietnam. https://www.gso.gov.vn/default_en.aspx?tabid=783. (Acccessed 13 November 2018).

IMF 2019. Report for selected countries and subjects, 2016. Gross domestic product per capita, current prices (U.S. dollars). https://www.imf.org/external/pubs/ft/weo/2017/01/weodata/weorept.aspx?pr.x=15&pr.y=6&sy=2016&ey=2016&scsm=1&ssd=1&sort=country&ds=.&br=1&c=548%2C924%2C582&s=NGDPDPC&grp=0&a=. (Accessed 25 October 2019).

Long, L.K., Flaaten, O., Kim Anh, N.T. (2008). Economic performance of open-access offshore fisheries-The case of Vietnamese longliners in the South China Sea. Fisheries Research 93: 296-304.https://doi.org/10.1016/j.fishres.2008.05.013

Ngoc, Q.T.K., Flaaten, O., Anh, N.T.K. 2009. Efficiency of fishing vessels affected by a marine protected area – The case of small-scale trawlers and the marine protected area in Nha Trang Bay, Vietnam. In: Integrated Coastal Zone Management, Moksness, E., Dahl, E., Josianne, S.(Eds.), Wiley-Blackwell., Norway, pp. 189-206.

Olson, K., Vu, L. (2009). Economic efficiency in farm households: trends, explanatory factors, and estimation methods. Agricultural Economics 40: 587-599.https://doi.org/10.1111/j.1574-0862.2009.00400.x

Pascoe, S., Coglan, L. (2002). The contribution of unmeasurable inputs to fisheries production: An analysis of technical efficiency of fishing vessels in the English channel. American Journal of Agricultural Economics 84: 585-597.https://doi.org/10.1111/1467-8276.00321

Pascoe, S., Hassaszahed, P., Anderson, J., Korsbrekke, K. (2003). Economic versus physical input measures in the analysis of technical efficiency in fisheries. Applied Economics 35: 1699-1710.https://doi.org/10.1080/0003684032000134574

Pham, T.D.T., Huang, H.W., Chuang, C.T. (2014). Finding a balance between economic performance and capacity efficiency for sustainable fisheries: Case of the Da Nang gillnet fishery, Vietnam. Marine Policy 44: 287-294.https://doi.org/10.1016/j.marpol.2013.09.021

Pomeroy, R., Kim Anh, N.T., Thong, H.X. (2009). Small-scale marine fisheries policy in Vietnam. Marine Policy 33: 419-428.https://doi.org/10.1016/j.marpol.2008.10.001

Simar, L., Wilson, P.W. (2000). Statistical inference in nonparametric frontier models: The state of the art. Journal of Productivity Analysis 13: 49-78.https://doi.org/10.1023/a:1007864806704

Simar, L., Wilson, P.W. (2007). Estimation and inference in two-stage, semi-parametric models of production processes. Journal of Econometrics 136: 31-64.https://doi.org/10.1016/j.jeconom.2005.07.009

Simm, J., Besstremyannaya, G. 2016. Package 'rDEA'. https://cran.r-project.org/web/packages/rDEA/rDEA.pdf. Accessed 11 December 2017.

Squires, D., Kirkley, J. (1999). Skipper skill and panel data in fishing industries. Canadian Journal of Fisheries and Aquatic Sciences 56: 2011-2018.https://doi.org/10.1139/f99-135

Sumaila, U.R., Khan, A., Watson, R., Munro, G., Zeller, D., Baron, N., Pauly, D. (2007). The World Trade Organization and global fisheries sustainability. Fisheries Research 88: 1-4.https://doi.org/10.1016/j.fishres.2007.08.017

Thap, L.V., Long, L.K., Hoai, N.T. 2016. Analysis of technical efficiency of intensive white-leg shrimp farming in Ninh Thuan, Vietnam: An application of the double-bootstrap data envelopment analysis. In IIFET 2016 Scotland Conference Proceedings. International Institute of Fisheries Economics and Trade (IIFET), Corvallis, USA.

https://ir.library.oregonstate.edu/concern/conference_proceedings_or_journals/q524jq64g. (Accessed 2 November 2017).

Tingley, D., Pascoe, S., Coglan, L. (2005). Factors affecting technical efficiency in fisheries: stochastic production frontier versus data envelopment analysis approaches. Fisheries Research 73: 363-376.https://doi.org/https://doi.org/10.1016/j.fishres.2005.01.008

Vasep. 2018. Whitebook on combating IUU fishing in Vietnam. Vietnam Association of Seafood Exporters and Producers, Vietnam. http://seafood.vasep.com.vn/while-book-iuu.html.

Zhang, Y., Bartels, R. (1998). The effect of sample size on the mean efficiency in DEA with an application to electricity distribution in Australia, Sweden and New Zealand. Journal of Productivity Analysis 9: 187-204.https://doi.org/10.1023/A:1018395303580

Paper II:

Nga Thi Hong Cao, Arne Eide, Claire W. Armstrong, Long Kim Le

Measuring technical efficiency in fisheries using physical or economic variables:

A data envelope analysis of a Vietnamese purse seine fishery

Manuscript

Measuring technical efficiency in fisheries using physical or economic variables:

A data envelope analysis of a Vietnamese purse seine fishery

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Abstract

Data Envelopment Analysis (DEA) studies of fisheries usually apply output-oriented efficiency based on physical measures. Although physical measures capture important input factors employed in fishing activities (such as boat size, engine power), economic measures directly reflect the cost of inputs employed. This case study investigates whether economic measures are vital or whether technical efficiency is sufficiently well reflected solely by the use of physical measures. The analysis makes use of a double bootstrap DEA technique and compares input-oriented technical efficiency based on physical versus economic measures. The double bootstrap technique was chosen as it allows statistical inference based on the estimated technical efficiency. The results show that economic measures give a lower technical efficiency than that obtained by physical measures. However, a significant difference in the technical efficiencies was found between the two measures. Truncated regression models indicated that factors such as skipper experience and interest payment significantly affect the physical

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measure of technical efficiency at the 5% level. This study concludes that physical variables are capable of capturing the essential economic differences between vessels.

Keywords: technical efficiency, double bootstrap DEA, economic variables, physical variables, purse seining

1. Introduction

While fishing is often recorded using physical indicators (e.g. vessel size, fishing time, number of fishers, and fuel consumption), economic indicators such as revenue, costs, and profit represent normal business indicators. Physical indicators are most frequently used in efficiency studies of fisheries employing Data Envelopment Analysis (DEA) (Kirkley et al., 2001), as such variables are easily available since they are often recorded and used in the management of fisheries (Pascoe et al., 2003). However, the use of physical versus economic variables may depend on the data available and the aims of the research. Although the latter types of data may be harder to obtain, they are often believed to be more comprehensive.

Economic data are generally measured in monetary terms, while physical data are measured along different quantity scales, such as length, volume, weight, and so on (Pascoe et al., 2003). Physical measures describe some important inputs employed in fishing activity, while economic measures are assumed to capture the full range of inputs employed (Pascoe et al., 2003; Pascoe and Robinson, 1998). Differences in materials applied for constructing vessels or on-board technology, for example, are presumably included in the amount of capital measured. While these types of inputs are neither readily available nor easy to include in the production function, the amount of capital can be measured either from the physical input (using engine power or boat size as a proxy for fixed capital) or in terms of value (the value of the vessel and fishing equipment). In addition, the composition of physical inputs is separable and clearly identified. This contrasts with economic measures, where the composition of all the inputs in the aggregate value measure may not be apparent (Pascoe et al., 2003).

When technical efficiency is measured by economic measures, it reflects the economically optimizing vessel behavior (economic optimization approach), maximizing profit or minimizing costs. Technical efficiency is then identified by the cost function (Atkinson and Cornwell, 1993) as the ratio between actual output and the corresponding frontier output. This is based on the dual relationship between cost and production functions. This is derived from an output-oriented approach. This approach is applied to estimate output-oriented technical efficiency when using stochastic production frontier functions with the corresponding behavioral objectives (catch maximization, revenue maximization) (Jamnia et al., 2015; Tingley et al., 2005). To employ this approach, economic data such as costs and outputs are required.

DEA is a non-parametric method based on available economic and/or physical variables that reflects the activity of each unit (a fishing vessel in our case). Economic variables measure technical efficiency, providing a production frontier of each unit, representing the optimal (maximum) production at different levels of input combinations. The dual perspective looks at a given production level, optimizing (minimizing) the combined inputs necessary to obtain this production level.

Physical measures (e.g. vessel size) are used as inputs in DEA in order to estimate technical efficiency, reflecting the technical relationship between the input and output of each vessel. Output-oriented technical efficiency is obtained by the ratio between actual physical output and maximum physical output. Similarly, input-oriented technical efficiency is defined by the minimum level of inputs used to sustain the current catch.

It is well known that there is no difference between the economically based technical efficiency and the physically based technical efficiency when vessels face the same prices. In practice, however, prices vary across vessels and the estimates of the two efficiencies will give different results (Cross and Färe, 2008).

The aim of this paper was to measure technical efficiency between fishing vessels in the case of using physical versus economic data sets and to investigate possible deviations in the estimation of efficiency. There are two approaches to measuring technical efficiency by DEA: by output or input orientation. Output-oriented technical efficiency is measured by the observed outputs at a given level of all inputs, while an input-oriented technical efficiency assumes a given level of outputs (Farrell, 1957). A major impetus for analyzing the input-oriented technical efficiency is that catches (outputs) in fisheries may be regulated at vessel level through non-transferable catch quotas (Andersen, 2005; Castilla-Espino et al., 2006). In contrast, the fishers want to maximize catch, revenue, and profit at a given set of inputs when output orientation is selected (Tingley et al., 2005).

A few empirical studies assume input-oriented technical efficiency in fisheries (Andersen, 2005; Castilla-Espino et al., 2006), while output orientation in general is more common (Tingley et al., 2005). In this study, an input orientation is chosen to reduce the input as much as possible while sustaining the current catch levels. This is a reasonable assumption for the cost-minimizing behavior of fishers in developing countries, where the following apply: (1) The running cost for a fishing trip is expensive but fishers' financial resources are limited since they often have difficulty obtaining formal credit access for the operational cost because of an imperfect financial market. (2) Fishers are considered as price takers when each vessel's small landing does not impact the price of fish in the competitive market (Duy et al., 2012; Long et al., 2008), which may be relevant for the behavior of the fishers that minimize the operational cost in their fishing activities. (3) Data for the analysis are based on a fishing year, not a fishing trip. When a fishing vessel goes to the fishing ground, inputs for a fishing trip are given, so catch-maximizing behavior of fishermen is plausible (this means that output-orientation is sensible if the data for the analysis are on a trip basis) (Tingley et al., 2005). For the whole fishing year, the cost-minimizing behavior of fishermen may be reasonable since they can easily change the number of fishing trips. (4) Fisheries are traditionally characterized by a high degree of stochasticity in catches due to factors such as stock and price fluctuations, weather, and luck; therefore, the catch and revenue of a fishing vessel may fluctuate considerably and may be uncontrollable (Andersen, 2005). This can be relevant for minimization of the cost level.

Our case study was a Vietnamese purse seine fishery, one of the most important inshore fisheries in Nha Trang, a city in the southern part of Vietnam. Like most Vietnamese fisheries, the purse seine fishery (accounting for 5% of the total fleet) is a multispecies and subsidized open access fishery. The seiners usually operate all year, while the main season is from January to September, mainly targeting anchovy and scads. Bycatches of other fish species (such as sardine, mackerel, and small tuna) account for less than 3% of the total catch landed. The average horsepower (hp) and hull length of the fleet were 303 hp and 16.05 meters, respectively, in 2016, and the average number of crew members was 14 per vessel (including the skipper). The educational level was low, with an average of six years in school.

Physical measures such as engine size and vessel hull length are core indicators in Vietnamese fisheries. Since the mid-1990s, purse seiners with engines larger than 90 hp located in Nha Trang have received subsidies aiming to encourage the fishing industry to carry out high sea operations. Hence, in 2016 the government covered most of the insurance costs, including the vessel and crew insurance costs of such vessels. In addition, preferential loans with low interest rates were issued to finance new vessels (Decree, 2014). Both with and without subsidies, most surveyed fishers reported having recently improved their vessels and invested in new and larger engines to enhance efficiency. Consequently, the fishing effort capacity of the fleet has increased considerably over recent years. In 2016, the Nha Trang purse seine fishing fleet included 130 vessels with a total engine capacity of about 40,000 hp. While the number of vessels has been quite stable since 2010 (a decrease of 3.7%), the engine capacity has increased by almost 170% (DECAFIREP, 2010, 2016).

2. Data Collection

A sample of 52 purse seiners was selected from a population of 130 purse seiners registered in 2016 at Khanh Hoa Department of Capture Fisheries and Resources Protection, Nha Trang. Information about the performance of the 52 vessels was collected from December 2016 to March 2017 at three different sites (Vinh Nguyen, Hon Ro, and Vinh Truong). The vessels were selected in order to reflect the average fleet properties in terms of hull length and horsepower. Table 1 shows the means and standard deviations of hull length and horsepower in the whole fleet and in the sample of the fleet along with the corresponding t-test statistics. The t-tests confirmed the representativeness of the sample with regard to hull length and horsepower. The t-test statistic is defined as $\frac{M_S - M_P}{SD/\sqrt{n-1}}$, where M_S and M_P represent the means of the sample and the population, respectively. *SD* is the standard deviation of the sample and *n* is the sample size. Table 1 shows that, in terms of hull length and engine size, our sample of 52 vessels did not differ significantly from the purse seine fleet because the t-test value is less than 2.008 at significance level 5%. This shows that the tested properties of the sample and the fleet were not found to differ.

Table 1. Sample and population averages and standard deviations of hull length and engine power and the t-tests of the sample.

Variable	**Sample size = 52**		**Population size = 130**		t-test statistics, at significance level 5%
	Mean	SD	Mean	SD	
Hull length	16.05	2.60	15.94	2.86	0.30
Engine power	303.10	163.27	300.35	173.29	0.12

Face-to-face interviews with vessel owners (and/or spouses) were conducted to collect technical and operational information in addition to costs and earnings. Average prices and quantities of each harvested species and various other economic and social factors of the purse seine fleet were also collected, in addition to the list of registered fishing vessels in Khanh Hoa in 2016 and other relevant information.

Table 2 shows pairwise correlations between economic and physical variables obtained in the survey. Physical inputs (horsepower, hull length, and fuel consumption) and economic inputs (fixed cost and variable costs) are positively correlated with the respective outputs, catch quantity of anchovy, and the revenue retrieved from this catch. In addition, the pairwise correlations between the physical and economic variables and the different variables are also shown in Table 3.

Table 2. Pearson correlation between the physical and economic variables. Darker green cell color indicates a significant correlation at the 5% level; light green color indicates significance at the 10% level.

	Revenue from anchovy	Revenue from scads	Revenue from other fish species	Anchovy	Scads	Others	Hull length	Horsepower	Fixed cost	Variable cost	Fuel	Loans	Man days at sea
Revenue from scads	0.17	1.00											
Revenue from other fish species	-0.60	-0.24	1.00										
Anchovy	1.00	0.17	-0.60	1.00									
Scads	0.17	1.00	-0.24	0.17	1.00								
Others	-0.60	-0.24	1.00	-0.60	-0.24	1.00							
Hull length	0.55	0.43	-0.26	0.55	0.43	-0.26	1.00						
Horsepower	0.58	0.35	-0.46	0.58	0.35	-0.46	0.80	1.00					
Fixed cost	0.37	0.42	-0.28	0.37	0.42	-0.28	0.47	0.53	1.00				
Variable cost	0.70	0.64	-0.42	0.70	0.65	-0.42	0.56	0.60	0.48	1.00			
Fuel	0.63	0.56	-0.29	0.63	0.56	-0.29	0.57	0.60	0.59	0.90	1.00		
Loans	0.39	0.21	-0.26	0.39	0.21	-0.26	0.32	0.39	0.30	0.44	0.36	1.00	
Man days at sea	0.80	0.57	-0.51	0.80	0.57	-0.51	0.59	0.59	0.62	0.87	0.81	0.36	1.00
Interest payment on loans	0.50	0.32	-0.20	0.50	0.32	-0.20	0.75	0.64	0.35	0.53	0.47	0.48	0.46

Table 3. Pearson correlation between the physical and economic variables and the different variables.

	Family size	Skipper experience
Revenue from anchovy	0.12	-0.13
Revenue from scads	-0.02	-0.17
Revenue from other fish species	0.02	0.21
Anchovy	0.12	-0.13
Scads	-0.02	-0.17
Others	-0.02	0.21
Hull length	-0.01	-0.19
Horsepower	-0.12	-0.21
Fixed cost	-0.05	-0.24
Variable cost	0.04	-0.04
Fuel	0.08	-0.04
Man days at sea	0.02	-0.20
Loans	0.13	0.04
Family size	1.00	0.25
Skipper experience	0.25	1.00
Interest payment	-0.12	-0.04

2.1 Selection of physical and economic variables

Capital and capital utilization are key inputs often used in fishery efficiency studies (Pascoe et al., 2003; Pascoe and Tingley, 2016). Capital can be measured in either physical or monetary terms. We measured the annual fixed cost of capital invested in monetary units when estimating the technical efficiency of the Nha Trang purse seine fishery. As in several corresponding studies (as by Duy et al., 2015; Guyader et al., 2004; Hoff et al., 2013; Lleonart et al., 2003), repair and maintenance costs of boats and fishing gear were considered as fixed costs in this study. Other studies treat such costs as variable costs (Dichmont et al., 2008; Huppert and Squires, 1986), while Pascoe et al. (2015) argue that these costs should be distributed into both fixed and variable costs, for example depending on fishing gear.

The fleet studied here was rather homogeneous, including the seasonal patterns of the fisheries. This suggests that it is reasonable to assume that repair and maintenance costs are fixed in this particular fishery, while in other fisheries they have to be treated as variable costs (for example, when seasonal length varies between vessels). In this study, total fixed cost was found by summing up the costs of insurance, fees, and depreciation of the vessel and fishing equipment in addition to the costs of maintenance and repair. Horsepower is a simple proxy for the fixed capital stock involving a single physical measure and was used by Pascoe et al. (2003) when estimating the technical efficiency of Norwegian trawlers. In this paper, horsepower and hull length were used as physical measures of the capital employed in fishing.

Fuel consumption was measured in both liters and value, providing inputs to the physical and economic models, respectively. The cost of fuel constitutes a major part of the variable costs. Other variable costs are, for example, lubricants, ice, and provisions (Duy et al., 2015; Long et al., 2008). In this study, variable cost is a proxy for variable inputs, which is chosen as an economic measure of capital utilization in the economically based technical efficiency model.

Labor cost was indirectly represented by the number of man days at sea, while other running costs encompassed the remaining variable costs. Man days at sea was defined as the number of fishing days multiplied by the number of crew members including the skipper. However, man days at sea and variable cost are highly correlated (see Table 2). Therefore, man days at sea (used as a proxy for the crew payment) was excluded from the economically based technical efficiency model (Pascoe et al., 2003). For the physically based technical efficiency model, man days at sea (as being a proxy for variable inputs) is also taken out of this model when the choice of fuel consumption measured in liters is better than that of days at sea because bad fishing luck may lead to more days at sea (Pascoe et al., 2003)

Physical outputs included the three catch quantities (anchovy, scads, and other fish species), while the economic outputs were the revenues obtained from the same catches (Table 4).

The selection of the physical and economic variables as described in Table 4 was done to purify the two models; that is, economic measures were not included in the physical model and vice versa. However, there were still other common variables in the two models, with an unknown impact on the final result. Additionally, there were available variables that were not utilized.

Table 4. Statistics of vessel variables obtained in 2016 in the sample of 52 purse seiners. SD represents the standard deviation of each sample of variables; Min. represents the absolute minimum and Max. the absolute maximum value within each sample of variables.

Variable	Unit	Mean	SD	Min.	Max.
Physical					
Input:					
Horsepower	Hp	303.1	163.3	50.0	730.0
Fuel	Liters (dm^3)	32,184.5	12,558.2	9,600.0	72,000.0
Hull length	Meters	16.1	2.6	11.0	22.9
Output (catch):					
Anchovy	Kg	122,139.5	63,063.7	0.0	255,000.0
Scads	Kg	34,922.3	47,416.7	0.0	240,000.0
Other fish species	Kg	3,624.1	11,394.1	0.0	47,600.0
Economic					
Input:					
Total fixed cost	million VND	263.7	111.2	76.0	627.7
Variable cost	million VND	757.6	280.3	228.0	1,438.5
Output (revenue):					
Anchovy	million VND	1,421.7	734.1	0.0	2,968.2
Scads	million VND	279.4	379.3	0.0	1,920.0
Other fish species	million VND	54.4	170.9	0.0	714.0
Variables used in both physical and economic DEA calculations					
Man days at sea	Days	2,660.0	897.4	600.0	4,500.0
Skipper experience	Years	26.8	7.2	11.0	39.0
Skipper experience squared	Years^2	769.0	364.8	121.0	1,521.0
Family size	Persons	5.0	1.4	3.0	10.0
Loans (dummy)	Yes (1)/No (0)	0.4	0.5	0.0	1.0
Interest payment	million VND	35.1	53.8	0.0	220.0

The lower part of Table 4 displays the common variables used in both models. These were man days at sea, family size, and skipper experience. Skipper experience was included in two different variables, motivated by the assumption that the expected positive effect of increasing experience will decline at some point. Age was assumed to be a proxy for the skipper's skills. The skills reflected the ability of the skipper to select the best fishing ground and to manage and supervise the crew in order to increase the catch quantities (output). The declining rate of increase in skill with age was obtained by a negative term for the skipper experience squared.

Family size was defined as the number of members in the skipper’s household. Livelihood conditions in the community depend on fishing, and an increase in the number of family members in a skipper’s household could cause an even greater dependency on fishing activities, in order to sustain the family. Furthermore, when many adult members in a fishing household take part in the family’s fishing activities, the labor force working on a fishing vessel tends to be more stable and labor costs can be expected to be lower, implying increasing technical efficiency. In this study, family size was considered as a proxy for crew payment.

Regarding man days at sea, it is expected that this variable will negatively impact the technical efficiency in open access fisheries. This means that more days at sea will lead to a lower technical efficiency, implying that a vessel with a short season will hit the peak season, while others must extend their fishing into low season periods. In that case, the selected method could be criticized because only more intense fishing during peak season could enhance cost efficiency.

Based on the data availability, loans are represented by a dummy variable which equals one in the case of the vessel owner having borrowed money and zero if not. Besides that, we expected that interest payment on loans may reduce technical efficiency by increasing total costs (Thap et al., 2016).

3. Methodology

A number of different approaches have been used to measure relative technical efficiency in fisheries. DEA (Castilla-Espino et al., 2014; Lindebo et al., 2007; Pascoe and Tingley, 2006; Pham et al., 2014), which is applied here, is often preferred over the stochastic production frontier (SPF) approach (Kirkley et al., 2002, 2004; Pascoe and Tingley, 2016), as it is a relatively simple technique based on a non-parametric approach and does not require a specification of the production frontier as in the SPF approach. Furthermore, DEA can incorporate multiple outputs in the analysis.

However, there are three main drawbacks that make the deterministic DEA problematic for statistical inference. Firstly, all estimates of technical efficiency are sample specific. Although the DEA method is deterministic, the efficiency is still computed relative to the estimated frontier rather than the true one. The efficiency scores obtained from a finite sample are subject to sampling variation of the estimated frontier (Simar and Wilson, 1998).

Secondly, the estimated technical efficiency measures tend to be too optimistic, due to the fact that the DEA estimate of the production set is necessarily a weak subset of the true production set under standard assumptions underlying DEA (Simar and Wilson, 2000). Simar and Wilson (1998, 2000) proposed a procedure based on the smoothed bootstrap method to provide statistical inference regarding technical efficiency measures, including estimation of unbiased confidence intervals of technical efficiency and hypothesis testing, in non-parametric frontier models.

The third drawback is related the problem of the conventional DEA two-step approach to explain the sources of firm-level efficiency, where efficiency is estimated in the first stage and then the estimated efficiencies are regressed on the environmental variables in the second stage. Simar and Wilson (2007) criticized the DEA technical efficiency estimates for being serially correlated. Therefore, standard inference approaches used in the conventional two-step DEA procedure are statistically invalid.

Based on the advantages of the smoothed bootstrap procedure they developed in 1998 and 2000, Simar and Wilson (2007) proposed two Algorithms to analyze the effect of the contextual factors on technical efficiency. Alogrithm 1 only gives the consistent inference for factors explaining efficiency. This study employed a double bootstrap procedure (Algorithm 2), which simultaneously provides not only unbiased confidence intervals for the technical efficiency estimate but also consistent inference for factors explaining efficiency.

The bootstrap is considered as a way to simulate a true sampling distribution by a Data Generating Process (DGP) from the original data set (Balcombe et al., 2008; Coelli et al., 2005; Olson and Vu, 2009). The DEA model applied here is re-estimated with the new data set or the pseudo replicate data generated by the original data set and this process is repeated many times to yield the empirical distributions of the estimators of the parameter of interest that give a Monte Carlo approximation of the sampling distribution and a feasible inference procedure. The DGP that provides the rationale for Simar and Wilson (2007) double bootstrap is used to estimate technical efficiency and explain the factors affecting technical efficiency.

The double bootstrap DEA procedure is performed by the following seven steps:

The first step is to estimate the technical efficiency (*TE*) in terms of input orientation for the 52 purse seiners (j = 1, ..., 52) in the sample, based on the DEA framework described by Equation (1) (see Andersen, 2005; Castilla-Espino et al., 2006).

$$TE_j(u,x) = \min \lambda_j$$

subject to:

$$\begin{aligned} & u_j \leq \sum_{j=1}^{52} \alpha_j \, u_j; \\ & \lambda_j x_j \geq \sum_{j=1}^{52} \alpha_j x_j; \\ & \alpha_j \geq 0 \ ; \\ & \sum_{j=1}^{52} \alpha_j = 1; \end{aligned} \qquad (1)$$

The technical efficiency (TE_j) is a function of outputs (u) and inputs (x). λ_j denotes the technical efficiency in terms of input orientation, with a value between zero and one, defining the smallest combination of inputs for a given level of outputs. If the value of TE_j equals one ($\lambda_j = 1$), the vessel is technically efficient, while the vessel is not technically efficient if $0 \leq TE_j < 1$.

x_j is the amount of the fixed and variable inputs of vessel j employed to produce outputs, while α_j is the intensity variable that is used to define the linear combination of the peers of the j^{th} vessel.

The DEA model above gives us the technical efficiency under the assumption of Variable Returns to Scale (VRS). If $\sum_{j=1}^{J} z_j < 1$, the production technology exhibits decreasing returns to scale, which implies that if we increase the inputs by, for example, 10%, the outputs will increase by less than 10%. The production technology exhibits increasing returns to scale ($\sum_{j=1}^{J} z_j > 1$) if we increase the inputs by, for example, 10%, the outputs will increase by more than 10% (increasing returns to scale). Technical efficiency when assuming Constant Returns to Scale (CRS) can be estimated by relaxing the constraint $\sum_{j=1}^{52} \alpha_j = 1$ in Expression (1) (Banker et al., 1984), which implies that if we increase the inputs by, for example, 10%, the outputs will increase by 10%.

The second step uses maximum likelihood theory to estimate $\hat{\beta}$ of β and $\widehat{\sigma_\varepsilon}\ of\ \sigma$ in the truncated regression of $\widehat{Y_j}$ on D_j as described by:

$$\widehat{Y_j} = \beta_0 + \beta_j D_j + \varepsilon_j \geq 1 \qquad (2)$$

The left-hand side of Equation (2) is the inverse of the technical efficiency (the technical efficiency score), $\widehat{Y_j} = 1/\widehat{\lambda_j}$, with a value ranging from one to infinity. D_j is the vector of exogenous variables affecting the technical efficiency of the purse seiners. β_0 is an intercept of the model while β_j is the corresponding vector of parameter values to be estimated by the truncated regression model. ε_j is a continuous independent and identically distributed random variable, normally distributed as $N(0, \sigma_\varepsilon^2)$ with left truncation at $\left(1 - \beta D_j\right)$ for each vessel j. It is assumed that ε_j and D_j are strictly independent. In this truncated regression model, ε_j represents the other exogenous variables outside the model (the effect of the omitted variables) and the measurement errors of inputs and outputs, as well as other stochastic noise components affecting technical efficiency. In other words, ε_j reflects the fact that the model partly explains the efficiency levels.

The third step of the bootstrap technique is to perform the procedure 100 times in a first loop to get a set of bootstrap efficiency estimates $E_j = \left\{\widehat{\Upsilon_{jb}^*}\right\}_{b=1}^{100}$. This is done by repeating the following four steps (i–iv) for each vessel:

(i) For each j = 1, …, 52, ε_j is drawn from N(0, $\hat{\sigma}_\varepsilon^2$).

(ii) For each j = 1, …, 52, compute $\Upsilon_j^* = \hat{\beta}_0 + D_j \widehat{\beta}_J + \varepsilon_j$.

(iii) Construct a pseudo data set $\left(X_j^*, \Upsilon_j^*\right)$, where $X_j^* = \left(\widehat{\Upsilon}_J / \Upsilon_J^*\right) X_j$ and $Y_j^* = Y$.

(iv) Using the pseudo data set and Expression (1), calculate pseudo efficiency estimates $\widehat{\Upsilon_J^*} = 1/\widehat{\lambda_j^*}$ for all j = 1, …, 52.

The next step is, for each j = 1, …, 52, to calculate the bias-corrected estimator $\widehat{\widehat{\Upsilon}}_J = \widehat{\Upsilon}_J - bias\left(\widehat{\Upsilon}_J\right)$, where the bias term is $bias\left(\widehat{\Upsilon}_J\right) = \left(1/L_1 \sum_{b=1}^{L1} \widehat{\lambda_{jb}^*}\right) - \widehat{\Upsilon}_J$. In this case, L_1 is the first loop repeated 100 times.

The fifth step is to apply the truncated maximum likelihood to the data set, regressing $\widehat{\widehat{\Upsilon}}_J$ on D_j in order to calculate estimates $\hat{\hat{\beta}}$ and $\widehat{\widehat{\sigma_\varepsilon}}$.

Then, the bootstrap technique is applied on the truncated regression model by repeating the following three steps (i–iii) 2000 times in the second loop, to generate a set of bootstrap estimates $F = \left\{\left(\widehat{\widehat{\beta^*}}, \widehat{\widehat{\sigma_\varepsilon^*}}\right)_b\right\}_{b=1}^{2000}$.

(i) For each j = 1, …, 52, $\varepsilon_j$is drawn from an $N(0, \hat{\hat{\sigma}}_\varepsilon)$ distribution.

(ii) For each j = 1, …, 52, compute $\Upsilon_j^{**} = \hat{\hat{\beta}}_0 + D_j\, \hat{\hat{\beta}}_j + \varepsilon_{j.}$

(iii) Adopting the truncated maximum likelihood, regress Υ_j^{**} on D_j to calculate estimates $\widehat{\widehat{\beta^*}}$ and $\widehat{\widehat{\sigma_\varepsilon^*}}$.

The last step is to use the bootstrap estimates F and the estimates $\hat{\hat{\beta}}$ and $\hat{\hat{\sigma}}_\varepsilon$ generated in the fifth step to construct confidence intervals for β_0, β_j, and σ_ε. The $(1-\alpha)\%$ confidence interval of β_j is constructed as the probability statement below:

$Pr\left(-b_{\alpha/2} \le \widehat{\widehat{\beta_j^*}} - \hat{\hat{\beta}}_j \le -a_{\alpha/2}\right) \approx 1-\alpha$ such that the estimated confidence interval for β_j is $\left[\hat{\hat{\beta}}_j + a^*_{\alpha/2}, \hat{\hat{\beta}}_j + b^*_{\alpha/2}\right]$. Similarly, the estimated confidence interval for β_0 is $\left[\widehat{\widehat{\beta_0}} + a^*_{\alpha/2}, \widehat{\widehat{\beta_0}} + b^*_{\alpha/2}\right]$.

Two main points should be considered when applying the double bootstrap as described above. The first point is that steps three and four employ a parametric bootstrap in the first-stage problem to produce bias-corrected estimates of technical efficiency, $\hat{\hat{\delta}}_j$. The parametric structure assumed in Algorithm 2, $\varphi(Z_j, \beta) = Z_j\beta$, shows that the double bootstrap adjusts the estimates, based not only on the input and output information but also on sociological factors. This idea has a link to the parametric approach of technical analysis, the stochastic production function proposed by Battese and Coelli (1995).

The second point referred to above is that in order to explain the sources of vessel efficiency, the truncated regression analysis is conducted in the last steps (referred to above) to explain factors affecting the bias-corrected technical efficiency. Since the dependent variable in Equation (2) is the reciprocal of technical efficiency, a positive relationship between technical efficiency and the independent variable exists if the sign of the estimated coefficient is negative, and a negative relationship exists if this coefficient obtains a positive value (Balcombe et al., 2008; Long et al., 2020).

Since the estimated input-oriented technical efficiency obtains values between zero and one, it creates a censoring problem where these values are removed when estimating the Tobit model or some OLS regression models (Burgess and Wilson, 1998). Therefore, performing a truncated regression with a maximum likelihood method for Equation (2) avoids this boundary problem. Simar and Wilson (2007) advocated the use of a truncated regression model that explicitly takes into account the bounded domain of the DEA efficiency estimates.

This study used R software with the rDEA package created by Simm and Besstremyannaya (2016). The double bootstrap DEA procedure was employed separately for each of the approaches. This method had two stages. The first stage, in the case of the physically based technical efficiency (physical model), estimated technical efficiency from physical inputs (hull length, horsepower, and fuel) and outputs (catch of anchovy, scads, and others), as presented in Table 4. The second stage employed the truncated regression model in which the different variables, such as man days at sea, fishing experience (with the two different variables), family size, loans, and interest payment (in the lower part in Table 4), were assumed to affect the level of technical efficiency. The variables of the initial physical model were estimated simultaneously along with those included in the bootstrapping. One hundred replications were used for the first loop to compute bias-corrected efficiency estimates and two thousand replications were used for the second loop, where the truncated regression model for the physical measures was bootstrapped. Similarly, this procedure was also applied to the economic data, where the first stage estimates the economically based technical efficiency (economic model) by using the economic inputs (total fixed cost, and variable cost) and outputs (revenue from anchovy, revenue from scads, and revenue from other fish species), as reflected in Table 4. The different variables in the lower part of Table 4 show the factors affecting the economically based technical efficiency via the truncated regression model in the second stage.

This study also applied joint models, using economic inputs and physical outputs, and vice versa, as well as combinations of physical and economic inputs and outputs. Results from these joint models are assessed in the discussion section.

4. Results

VRS was selected for both models in the estimation of technical efficiency in this paper. A number of possible factors not included in Equation (1) could potentially cause fishers not to operate optimally, such as environmental fluctuations, constraints on financing, and different socio-economic characteristics (Coelli et al., 2005). The VRS DEA model might indirectly accommodate some of these factors better than the CRS model.

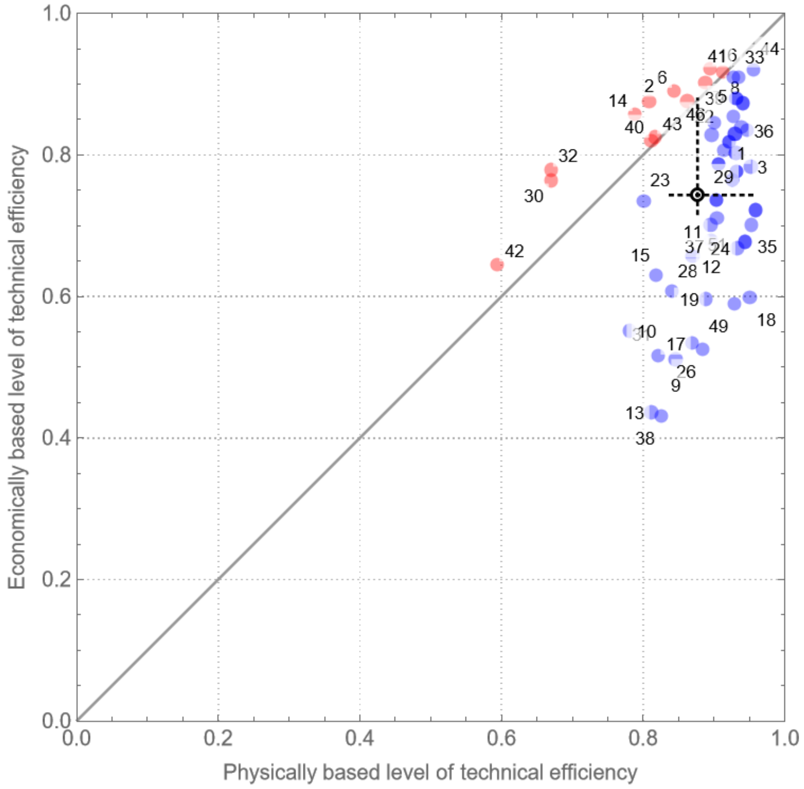

Figure 1. Physically and economically based technical efficiencies estimated using the double bootstrap DEA method for 52 vessels. The red color presents the vessels that are more technically efficient according to the economic measure, while the blue color indicates those that are more technically efficient according to the physical measure. The diagonal represents the perfect fit between the technical efficiencies of the two measures. The open circle represents the average values of the two methods, and the dashed lines show the corresponding 95% confidence intervals in both directions.

Table 5. Calculated technical efficiency (TE) in the sample of 52 purse seiners, based on the double bootstrap DEA method. TE_P: physically based technical efficiency; TE_E: economically based technical efficiency. SD refers to the standard deviation and CI to the 95% confidence interval.

Criterion	Median	Average	SD	Min.	Max.	Lower CI	Upper CI
TE_P	0.899	0.877	0.077	0.594	0.958	0.834	0.941
TE_E	0.778	0.743	0.135	0.431	0.922	0.68	0.82

Figure 1 shows the estimated technical efficiencies using the physical versus the economic model when applying the double bootstrap DEA method (see the black dots). Table 5 shows an average physically based technical efficiency of 0.877, while the average economically based technical efficiency was 0.743. In addition, the lower and upper boundaries of the 95% confidence interval for the physically based technical efficiency were 0.834 and 0.941, respectively, which suggests that the amount an "average" vessel could reduce its inputs by increasing its physically based technical efficiency ranged from about 6% to more than 16%. The lower and upper boundaries of the 95% confidence interval for the economically based technical efficiency were 0.68 and 0.82, respectively, which suggests that an "average" vessel could reduce the cost of its inputs by increasing its economically based technical efficiency from 18 to 32%. The median comparison test revealed a significant difference between the physical and the economic input-oriented technical efficiency at the 5% level.

Table 6. Determinants of the technical efficiency scores (the inverse of physically and economically based technical efficiencies) when using double bootstrap estimation. The first column presents the coefficients when using physical measures and the second, the corresponding figures when using economic measures.

Variable	Coefficient when using physical measures	Coefficient when using economic measures
Intercept	1.3721**	0.2084
Man days at sea	-0.0001	-0.0002
Skipper experience	-0.0253**	0.0746
Skipper experience^2	0.0005**	-0.0007
Family size	-0.0172	-0.0094
Loans	0.2744*	0.0422
Interest payment	0.002**	-0.002
Standard deviation of errors in the truncated regression	0.1875	0.3856

***,*: Significant at the levels of 5 and 10%, respectively*

Table 6 shows that the physically based technical efficiency increased with the experience of the skippers, but at a decreasing rate. However, these results were statistically significant at the 5% level for the physical model only, as presented in Table 6. A negative but not significant relationship was found between family size (used as a proxy for the payment of crews) and technical efficiency in both models.

There is a negative relationship between the loans and the physically based technical efficiency at the 10% level. A similar relationship is observed between the interest payment and technical efficiency at the 5% level. Otherwise, this contrasts with the truncated model of the economically based technical efficiency for these two cases.

We observe from Table 6 that the sizes of the intercepts of these truncated regression models differ and the intercept of the physical model is about 1.2 greater than that of the economic model. This indicates different random noise impacts on the models. However, only the intercept of the physical model is statistically significant, at the 5% level. Moreover, the finding of the truncated regression model regarding the physically based technical efficiency score indicates that the standard deviation of the error of this model is smaller than that obtained by the economic method (see Table 6).

The differences between the estimates of the two truncated regression models could be explained by measurement error and differences in the use of input measures when calculating physically and economically based technical efficiencies. In addition, since output prices may lead to a bias in the estimate of the economically based technical efficiency, this may be an explanation for the insignificant results in the economic model. Moreover, other factors affecting technical efficiency include the impact of subsidies, the political arguments for subsidies, variability in weather conditions, stock sizes and distributions, and possible market variations. However, such variables were not addressed in this study.

5. Discussion and Conclusion

The estimated average technical efficiency found by physical variables was higher than the average of economically based variables, and there was a significant difference between the two when doing the median comparison test. One reason for this may be that the economic inputs include a larger part of the factors involved in the production process than the physical variables do. Collection of economic data is often dependent on fishers' self-reports regarding their costs, revenues, and profits, which may be less accurate than the physical data. On the other hand, physical data only indirectly reflect the economic realities but could substitute for missing economic measures. Hence, there are issues of uncertainty in the use of both methods, which may also be reflected in the differences in technical efficiencies found by the two methods in this study.

Regarding the factors affecting technical efficiencies, Nga et al. (2020) showed that capacity utilization is an increasing function of skippers' fishing experience, but at a decreasing rate. The estimated parameter values were statistically significant at the 10% level when assuming a single output (total revenue) in the Nha Trang purse seine fishery. This corresponds to the current study. Family size did not influence technical efficiency in this paper, whereas Ngoc et al. (2009) found that family size negatively affected the technical efficiency of a Nha Trang trawl fishery and that skippers' fishing experience positively influenced the technical efficiency when assuming a linear relationship. However, the latter estimate was not found to be statistically significant. Thap et al. (2016) determined that there is a negative relationship between financial stress (loans) and technical efficiency at the 5% level. This result corresponds to the current paper. This is the same as loans: the interest payment on loans also impacts the technical efficiency negatively because total operating costs will increase since fishers receive credit with tight schedules for paying the loans off.

The signs of the skipper experience variables (two variables) and loans in the physical and economics models are opposite to one another. This difference may be due to output prices and measurement errors.

The physical and economic measures of the fixed inputs were correlated. Additionally, the variable inputs (fuel and variable cost) showed high correlation coefficients. The correlation matrix in Table 2 shows a larger variety in the correlations between input variables and output measures. When the coefficients of the skipper experience and interest payment variables in the lower part in Table 4 differ significantly from zero (at the 5% level) (Table 6), fixed costs, variable costs, revenue from anchovy, revenue from scads, and revenue from other species are economic variables used to build the economically based technical efficiency. Correspondingly, horsepower, hull length, fuel, anchovy, scads, and others are the only physical variables affecting the physically based technical efficiency. The results presented in Table 5 are consistent with the hypothesis that there were significant differences in technical efficiency when using physical and economic measures in the data set, in both average values and ranges. In addition, the average physically based technical efficiency was higher than the average economically based technical efficiency, while about 55% of all vessels showed quite similar efficiency levels using the two measures (see Figure 1). Moreover, the width of the 95% confidence interval for technical efficiency using physical measures was 0.11, while for technical efficiency using economic measures it was 0.14 (see Table 5). This indicates that there was lower statistical uncertainty in the technical efficiency estimate using physical measures. This may be due to physical data being more robust and more easily identifiable than economic data.

Furthermore, in this study sample, seven vessels in particular displayed a large difference in technical efficiency between the two methods. Seven of the 52 purse seiners had technical efficiency values between 43 and 59% when using economic measures, while the corresponding technical efficiency range was 81–93% for the physical variables. The difference in technical efficiency ranged from about 60% to more than 90% between the uses of physical versus economic variables for these seven vessels. These seven vessels had relatively high costs in common, which strongly impacted the technical efficiency measured by economic input variables. Some factors may explain this. The seven vessels were old ones with relatively high expenditures for repairs and maintenance. Old engines and time spent maintaining the vessels also affected fishing efficiency.

If the seven vessels referred to above are treated as outliers and excluded from the dataset, the average physically based technical efficiency would be 0.90 and the corresponding average economically based technical efficiency 0.789 when using the double bootstrap DEA procedure. A median comparison test (non-parametric test) showed a significant difference between the two at a 5% significance level. Regarding the factors affecting the two methods of measuring technical efficiency, skipper experience (embedded in two different variables) significantly (at the 5% level) influenced the physically and economically based technical efficiency. Otherwise, loans and interest payment on the loans significantly affected the physically based technical efficiency.

The findings above show that excess capacity existed in the purse seine fleet in the year studied. This represents an economic loss and may indicate a potential threat of overfishing. If the excess capacity is fully utilized, the overfishing issue could become more critical. However, this study cannot determine whether the purse seine fishery is characterized by overcapacity over time, as the crucial biological factors are unknown and the data were collected over one year only. However, the results show that two vessels had low relative technical efficiency using the economic measures. It is not known if these vessels were more efficient in other years, due to factors such as changes in fish distribution patterns or weather conditions. Random noise in production potentially plays a significant role in fisheries, possibly reflected in fleet diversity (Nga et al., 2020).

Fisheries are traditionally characterized by a high degree of stochasticity in catches due to factors such as stock and price fluctuations, weather, and luck, which also may affect efficiency (Fousekis and Klonaris, 2003; Jeon et al., 2006; Ngoc et al., 2009). Although these variables were not part of our survey, the intercept of the truncated regression model may include the impacts of these variables on technical efficiency, though this is only statistically significant at the 5% level for the physical model (see Table 6). This study suggests that the double bootstrap DEA method could be used more widely in fishery efficiency studies in which random noise significantly affects the production process. In this study, possible effects of stock changes over time were not included. Hence, a further study should preferably include panel data to measure the change in technical efficiency over several years.

Most fishery managers worldwide apply physical data to manage fisheries while fishers largely consider economic data such as revenues and costs in order to determine the economic status of their fishing operations on an annual basis. The findings here indicate that there is a significant difference in estimated technical efficiency measures when using physical versus economic data in a Vietnamese purse seine fishery. Clearly, physical data for estimating technical efficiency provide useful information for policymakers regarding the situation in a fishery. Such estimations may be expanded in cases where economic data are easily obtained. The additional benefits of considering economic information may, on the margin, be important, particularly if fleet reduction schemes are to be implemented (Pascoe and Tingley, 2006). This study shows the importance of collecting not only physical but also economic data if that is possible. The combined data give a better understanding of the condition of the fishery and could provide a better background for the development of management policies for sustainable fisheries in the future.

We also applied joint models, using economic inputs and physical outputs and vice versa, as well as combinations of physical and economic inputs and outputs. Applying the double bootstrap DEA method, we obtained a technical efficiency indicator equal to 0.88 when using horsepower, fuel, and hull length as inputs and revenues from anchovy, scads, and other fish species as outputs. The indicator was 0.739 when using variable costs and fixed costs as inputs and catch quantities of anchovy, scads, and other fish species as outputs. The technical efficiency indicator equaled 0.76 when employing fuel and fixed costs as inputs and the catch quantities of anchovy, scads, and other fish species as outputs. The corresponding value was 0.762 when using fuel and fixed costs as inputs and revenue from anchovy, scads, and other fish species as outputs. The indicator equaled 0.864 when applying horsepower, hull length, and variable costs as inputs and revenue from anchovy, revenue from scads, and revenue from other fish species as outputs. Finally, the technical efficiency indicator equaled 0.867 when applying horsepower, hull length, and variable costs as inputs and catch quantities of anchovy, scads, and other fish species as outputs. When using a 5% significance level, the first estimated technical efficiency indicator listed here (0.88) was significantly different from the TE_E but not from the TE_P. The three next cases (indicator values of 0.739, 0.76, and 0.762) had the opposite properties, being significantly different from the TE_P but not from the TE_E. The two last cases (indicator values of 0.864 and 0.867) were related to the TE_E and TE_P as in the first case. In general, the higher indicator values differed systematically and significantly from the TE_E, while the relatively lower values differed from the TE_P.

Regarding the factors affecting technical efficiency when mixing physical and economic input and output measures as presented above (the joint models), we found that the factors in the first model including skipper experience and interest payment significantly affected the technical efficiency at the level of 5%. In addition, only interest payment significantly affected the final model at the 5% level.

The average physically and economically based technical efficiencies of the fleet were 0.877 (estimated to be 0.834 at the lower limit and 0.941 at the upper limit of the 95% confidence interval) and 0.743 (estimated to be 0.68 at the lower limit and 0.82 at the upper limit of the 95% confidence interval), respectively, when using the double bootstrap DEA. This indicates that to sustain the current catch levels, expected inputs should be reduced by 5.9–16.6% based on the physical measures and by 18–32% based on the economic measures. In the last decade, the development of the Nha Trang purse seine fleet has been enhanced by subsidies. In general, it is acknowledged that subsidies may lead to an economically inefficient industry and an increase in the probability that fish stocks will be exploited beyond their biological limits (Sumaila et al., 2007). Instead of financial support, other types of governmental support (such as training fishermen, providing information on the state of fish stocks, weather forecasts, rescue and life-saving activities in high seas) which avoid further effort expansion could be offered.

Non-parametric DEA is based on the assumption that all the observed units belong to the attainable set. In such deterministic frontier models, statistical inference is now achievable by the use of bootstrap procedures. However, noise was not considered in the DGP of the bootstrap procedures proposed by Simar and Wilson (2008) (see Simar and Zelenyuk, 2011). In the presence of noise, envelopment estimators could behave dramatically since they may be very sensitive to extreme observations that might result only from noise. Due to the stochastic nature of fisheries, future studies could beneficially consider some procedures, for example those proposed by Simar (2007) and Simar and Zelenyuk (2011), who introduced noise in non-parametric frontier models (see also Olesen and Petersen, 2016).

Acknowledgments

We wish to thank the Norhed project SRV-13/0010 for providing financial support for the data collection. We are also grateful for the valuable input from the committee at the Arctic University of Norway.

References

Andersen, J.L., 2005. Production Economic Models of Fisheries: Vessel and Industry Analysis. PhD, Fisheries Economics and Management Division, Food and Resource Economic Institute, The Royal Veterinary and Agricultural University (KVL), Denmark.

Atkinson, S.E., Cornwell, C., 1993. Measuring technical efficiency with panel data: A dual approach. Journal of Econometrics. 59, 257-261.https://doi.org/https://doi.org/10.1016/0304-4076(93)90025-Z

Balcombe, K., Fraser, I., Latruffe, L., Rahman, M., Smith, L., 2008. An application of the DEA double bootstrap to examine sources of efficiency in Bangladesh rice farming. Applied Economics. 40, 1919-1925.https://doi.org/10.1080/00036840600905282

Banker, R.D., Charnes, A., Cooper, W.W., 1984. Some model for estimating technical and scale inefficiency in data envelopment analysis. Management Science. 2, 429-444.https://doi.org/10.1287/mnsc.30.9.1078

Battese, G.E., Coelli, T.J., 1995. A model for technical inefficiency effects in a stochastic frontier production function for panel data. Empirical Economics. 20, 325-332.https://doi.org/10.1007/BF01205442

Burgess, J.F., Wilson, P.W., 1998. Variation in inefficiency among Us hospitals. INFOR: Information Systems and Operational Research. 36, 84-102.https://doi.org/10.1080/03155986.1998.11732348

Castilla-Espino, D., García-del-Hoyo, J.J., Metreveli, M., Bilashvili, K., 2014. Fishing capacity of the southeastern Black Sea anchovy fishery. Journal of Marine Systems. 135, 160-169.https://doi.org/10.1016/j.jmarsys.2013.04.013

Castilla-Espino, D., Ordaz, F.G., Sharp, B.M.H., 2006. Efficiency and capacity of fully exploited fisheries managed using vessel catch limits combined with effort restrictions. In IIFET 2006 Portsmouth Proceedings., Corvallis, Oregon, USA. https://ir.library.oregonstate.edu/concern/conference_proceedings_or_journals/9w032417v

Coelli, T.J., Rao, D.S.P., O'Donnell, C.J., Battese, G.E., 2005. An introduction to efficiency and productivity analysis, second ed. Springer Science and Business Media, New York.

Cross, R., Färe, R., 2008. Farrell efficiency under value and quantity data. Journal of Productivity Analysis. 29, 193-199.https://doi.org/10.1007/s11123-007-0080-4

DECAFIREP, 2010. The annual report of the number of vessels and engine power registered in 2010. Khanh Hoa's Department of Captures Fisheries and Resource Protection (DECAFIREP), Vietnam. http://snnptntkh.gov.vn/news/us/dep/news_detail.aspx?id=20200110170523209975 6.48&idDV=0.5.

DECAFIREP, 2016. The annual report of the number of vessels and engine power registered in 2016. Khanh Hoa's Department of Captures Fisheries and Resource Protection (DECAFIREP), Vietnam. http://snnptntkh.gov.vn/news/us/dep/news_detail.aspx?id=202001101705232099756.48&idDV=0.5.

Decree, 2014. Decree 67/QD-TTg by Vietnam's Prime Minister on July, 7, 2014, on some polices related to fisheries development. https://thuvienphapluat.vn/van-ban/Bo-may-hanh-chinh/Nghi-dinh-67-2014-ND-CP-chinh-sach-phat-trien-thuy-san-238831.aspx?tab=1 (Accessed 07 January 2018).

Dichmont, C.M., Deng, A., Punt, A.E., Ellis, N., Venables, W.N., Kompas, T., Ye, Y., Zhou, S., Bishop, J., 2008. Beyond biological performance measures in management strategy evaluation: Bringing in economics and the effects of trawling on the benthos. Fisheries Research. 94, 238-250.https://doi.org/https://doi.org/10.1016/j.fishres.2008.05.007

Duy, N.N., Flaaten, O., Anh, N.T.K., Ngoc, Q.T.K., 2012. Open-access fishing rent and efficiency-The case of gillnet vessels in Nha Trang, Vietnam. Fisheries Research. 127-128, 98-108.https://doi.org/10.1016/j.fishres.2012.04.008

Duy, N.N., Flaaten, O., Long, L.K., 2015. Government support and profitability effects - Vietnamese offshore fisheries. Marine Policy. 61, 77-86.https://doi.org/10.1016/j.marpol.2015.07.013

Farrell, M.J., 1957. The measurement of productive efficiency. Journal of the Royal Statistical Society Series A (General). 120, 253-290.https://doi.org/10.2307/2343100

Fousekis, P., Klonaris, S., 2003. Technical efficiency determinants for fisheries: a study of trammel netters in Greece. Fisheries Research. 63, 85-95.https://doi.org/https://doi.org/10.1016/S0165-7836(03)00019-5

Guyader, O., Daures, F., Fifas, S., 2004. A Bioeconomic Analysis of the Impact of Decommissioning Programs: Application to a Limited-Entry French Scallop Fishery. Marine resource economics. 19, 225-242.https://doi.org/10.1086/mre.19.2.42629430

Hoff, A., Andersen, J.L., Christensen, A., Mosegaard, H., 2013. Modelling the economic consequences of Marine Protected Areas using the BEMCOM model. Journal of bioeconomics. 15, 305-323.https://doi.org/10.1007/s10818-012-9135-3

Huppert, D.D., Squires, D., 1986. Potential Economic Benefits and Optimum Fleet Size in the Pacific Coast Trawl Fleet. Marine resource economics. 3, 297-318.https://doi.org/10.1086/mre.3.4.42628967

Jamnia, A.R., Mazloumzadeh, S.M., Keikha, A.A., 2015. Estimate the technical efficiency of fishing vessels operating in Chabahar region, Southern Iran. Journal of the Saudi Society of Agricultural Sciences. 14, 26-32.https://doi.org/https://doi.org/10.1016/j.jssas.2013.04.005

Jeon, Y., Omar, I.H., Kuperan, K., Squires, D., Susilowati, I., 2006. Developing country fisheries and technical efficiency: the Java Sea purse seine fishery. Applied Economics. 38, 1541-1552.https://doi.org/10.1080/00036840500400525

Kirkley, J., Paul, C.J.M., Squires, D., 2002. Capacity and capacity utilization in common-pool resource industries: Definition, measurement, and a comparison of approaches. Environmental and Resource Economics. 22, 71-97.https://doi.org/10.1023/A:1015511232039

Kirkley, J., Paul, C.J.M., Squires, D., 2004. Deterministic and stochastic capacity estimation for fishery capacity reduction. Marine Resource Economics. 19, 271-294.https://doi.org/10.1086/mre.19.3.42629435

Kirkley, J.E., Färe, R., Grosskopf, S., McConnell, K., Squires, D.E., Strand, I., 2001. Assessing Capacity and Capacity Utilization in Fisheries When Data Are Limited. North American Journal of Fisheries Management. 21, 482-497.https://doi.org/10.1577/1548-8675(2001)021<0482:ACACUI>2.0.CO;2

Lindebo, E., Hoff, A., Vestergaard, N., 2007. Revenue-based capacity utilisation measures and decomposition: The case of Danish North Sea trawlers. European Journal of Operational Research. 180, 215-227.https://doi.org/10.1016/j.ejor.2006.03.050

Lleonart, J., Maynou, F., Recasens, L., Franquesa, R., 2003. A bioeconomic model for Mediterranean fisheries, the hake off Catalonia (Western Mediterranean) as a case study. Scientia marina. 67, 337-351.https://doi.org/10.3989/scimar.2003.67s1337

Long, L.K., Flaaten, O., Kim Anh, N.T., 2008. Economic performance of open-access offshore fisheries-The case of Vietnamese longliners in the South China Sea. Fisheries Research. 93, 296-304.https://doi.org/10.1016/j.fishres.2008.05.013

Long, L.K., Van Thap, L., Hoai, N.T., Pham, T.T.T., 2020. Data envelopment analysis for analyzing technical efficiency in aquaculture: The bootstrap methods. Aquaculture

Economics and Management. 24, 1-25 https://doi.org/10.1080/13657305.2019.1710876

Nga, C.T.H., Eide, A., Armstrong, C.W., Long, L.K., 2020. Economic performance and capacity utilisation in Vietnamese purse seine fishery. Asian Fisheries Science. 33, 58-64.https://doi.org/https://doi.org/10.33997/j.afs.2020.33.1.007

Ngoc, Q.T.K., Flaaten, O., Anh, N.T.K., 2009. Efficiency of fishing vessels affected by a marine protected area – The case of small-scale trawlers and the marine protected area in Nha Trang Bay, Vietnam, in: Moksness, E., Dahl, E., Josianne, S. (Eds.), Integrated Coastal Zone Management. Wiley-Blackwell., Norway, pp. 189-206.

Olesen, O.B., Petersen, N.C., 2016. Stochastic Data Envelopment Analysis—A review. European Journal of Operational Research. 251, 2-21.https://doi.org/https://doi.org/10.1016/j.ejor.2015.07.058

Olson, K., Vu, L., 2009. Economic efficiency in farm households: trends, explanatory factors, and estimation methods. Agricultural Economics. 40, 587-599.https://doi.org/10.1111/j.1574-0862.2009.00400.x

Pascoe, S., Robinson, C., 1998. Input Controls, Input Substitution and Profit Maximisation in the English Channel Beam Trawl Fishery Journal of Agricultural Economics. 49, 16–33.

Pascoe, S., Hassaszahed, P., Anderson, J., Korsbrekke, K., 2003. Economic versus physical input measures in the analysis of technical efficiency in fisheries. Applied Economics. 35, 1699-1710.https://doi.org/10.1080/0003684032000134574

Pascoe, S., Tingley, D., 2006. Economic capacity estimation in fisheries: A non-parametric ray approach. Resource and Energy Economics. 28, 124-138.https://doi.org/10.1016/j.reseneeco.2005.06.003

Pascoe, S., Vieira, S., Thebaud, O., 2015. Allocating repairs and maintenance costs to fixed or variable costs in fisheries bioeconomic models. Applied economics letters. 22, 127-131.https://doi.org/10.1080/13504851.2014.929619

Pascoe, S., Tingley, D., 2016. Capacity and technical efficiency estimation in fisheries: Parametric and non-parametric techniques, in: Weintraub, A., Romero, C., Bjørndal, T., Epstein, R. (Eds.), International Series in Operations Research and Management Science. Springer., New York, pp. 273-294.

Pham, T.D.T., Huang, H.W., Chuang, C.T., 2014. Finding a balance between economic performance and capacity efficiency for sustainable fisheries: Case of the Da Nang gillnet fishery, Vietnam. Marine Policy. 44, 287-294.https://doi.org/10.1016/j.marpol.2013.09.021

Simar, L., Wilson, P.W., 1998. Sensitivity analysis of efficiency scores: How to bootstrap in nonparametric frontier models. Management Science. 44, 49-61.https://doi.org/10.1287/mnsc.44.1.49

Simar, L., Wilson, P.W., 2000. Statistical Inference in Nonparametric Frontier Models: The State of the Art. Journal of Productivity Analysis. 13, 49-78.https://doi.org/10.1023/a:1007864806704

Simar, L., 2007. How to improve the performances of DEA/FDH estimators in the presence of noise? Journal of Productivity Analysis. 28, 183-201.https://doi.org/10.1007/s11123-007-0057-3

Simar, L., Wilson, P.W., 2007. Estimation and inference in two-stage, semi-parametric models of production processes. Journal of Econometrics. 136, 31-64.https://doi.org/10.1016/j.jeconom.2005.07.009

Simar, L., Wilson, P.W., 2008. Statistical Inference in Nonparametric Frontier Models: Recent Developments and Perspectives, in: Fried, H., Lovell, C., Schmidt, S. (Eds.), The measurement of productive efficiency. Oxford University Press., New York, pp. 423-521.

Simar, L., Zelenyuk, V., 2011. Stochastic FDH/DEA estimators for frontier analysis. Journal of Productivity Analysis. 36, 1-20.https://doi.org/10.1007/s11123-010-0170-6

Simm, J., Besstremyannaya, G., 2016. Package 'rDEA'. https://cran.r-project.org/web/packages/rDEA/rDEA.pdf (Accessed 11 December 2017).

Sumaila, U.R., Khan, A., Watson, R., Munro, G., Zeller, D., Baron, N., Pauly, D., 2007. The World Trade Organization and global fisheries sustainability. Fisheries Research. 88, 1-4.https://doi.org/10.1016/j.fishres.2007.08.017

Thap, L.V., Long, L.K., Hoai, N.T., 2016. Analysis of technical efficiency of intensive white-leg shrimp farming in Ninh Thuan, Vietnam: An application of the double-bootstrap data envelopment analysis. In IIFET 2016 Scotland Conference Proceedings, Corvallis, USA. https://ir.library.oregonstate.edu/concern/conference_proceedings_or_journals/q524jq64g

Tingley, D., Pascoe, S., Coglan, L., 2005. Factors affecting technical efficiency in fisheries: stochastic production frontier versus data envelopment analysis approaches. Fisheries Research. 73, 363-376.https://doi.org/https://doi.org/10.1016/j.fishres.2005.01.008

Paper III:

Cao Thi Hong Nga, Arne Eide

Fishermen's perceptions of negative events affecting fishing activities. A case study of a Vietnamese purse seine fishery.

Manuscript

Fishermen's perceptions of negative events affecting fishing activities. A case study of a Vietnamese purse seine fishery.

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Abstract

This paper focuses on fishermen's perceptions of how environmental and social-economic factors influence their lives and activities. A sample of Vietnamese purse seine fishermen were asked about their perceptions of changes in heavy waves, bad weather, storms/tropical cyclones, high temperatures, heavy rains, fish abundance, costs of fishing, suitability of fishing gear and boats, health, crew access and the availability of capital. Uncertainties related to these factors sum up the fishermen's major concerns. Most fishermen believe that the frequency and intensity of storms/tropical cyclones are increasing in Vietnam. Almost all of the surveyed fishermen expected the frequency and severity of rainfall and the average temperature to increase in the future and fish stock availabilities to decline. However, climate change is not expected to be among the most important negative factors in the future. Other factors, such as cost of fishing, health conditions, fishing gear and boats and the resource situation represent greater concerns among fishermen. Most of the worries fishermen currently have are confirmed by recent local observations when they are available. However, increasing frequencies of storms and

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precipitation were not observed, while the fishermen claimed such factors create problems for their current fishing activities.

Key words: fishermen’s perceptions, climate change, fish abundance, livelihood, purse seining.

1. Introduction

Fishing activities take place in a shifting natural environment and may be affected by a number of different environmental and social events. Natural events such as storms and cyclones, flooding, heavy rain and big waves make fishing difficult or impossible during periods. Other natural processes may have seasonal or long-term consequences, such as ecosystem perturbations and changes in fish distributions and abundancies. Social and economic factors, such as market changes and living conditions in general, also affect fishing activities in different ways.

This study focuses on the perception of Vietnamese fishermen regarding some of these factors and their affect on fishing activities. A group of 52 purse seiners were included in a survey where fleet capacity utilisation was also evaluated (published by Nga et al., 2020; Cao et al., 2021). The same group was asked a number of questions on their perceptions of the importance and future expectations of different factors affecting fishing activities. The purse seiners mainly target anchovy, *Stolephorus commersonnii* Lacepède, 1803, but also scads, *Decapterus russelli* (Rüppell, 1830), *Decapterus macrosoma* Bleeker, 1851, and *Decapterus maruadsi* (Temminck and Schlegel, 1843), small tuna (mackerel, *Scomberomorus guttatus* (Bloch and Schneider, 1801) and skipjack tuna, *Katsuwonus pelamis* (Linnaeus, 1758)) along the coastal area close to the city of Nha Trang. The general declining trend in catch per unit of horsepower (hp) of Vietnamese fisheries, from 0.89 tonnes per hp in 1991 (Pomeroy et al., 2009) to 0.32 tonnes per hp in 2016 (GSO, 2018; Vasep, 2018) reflects declining fish densities, probably due to overfishing by an increasing fishing capacity. Most fishermen in the purse seine fleet have low educational levels, with an average of six years in school, and there are few alternative livelihoods for this group.

Over the last few years, with and without government subsidies, fishermen have invested in upgrading their vessels and equipped them with modern fishing gear in order to increase fishing efficiency.

In 2016, nearly 8,500 vessels with an average engine size of 65 hp were present in the Khanh Hoa region. The Nha Trang purse seine fishing fleet went through significant changes during the period of 2009–2016. Average hull length modestly increased from 14 to almost 16 meters while the average engine size increased from about 100 hp to more than 300 hp (DECAFIREP, 2010, 2016). About 12% of the 130 Nha Trang purse seiners still have engines smaller than 90 hp, but almost one third of the fleet now have engines between 250 hp and 400 hp. Another third have engines larger than 400 hp (DECAFIREP, 2016). The fleet development is largely driven by subsidies from the Vietnamese government, motivated by increasing fishing efficiency but also the protection of national security and sovereignty of territorial waters.

Currently the Khanh Hoa region has five fishing harbours, and two of them, Hon Ro and Vinh Truong, are found in Nha Trang. Hon Ro is the largest fishing harbour in the South Central region.

Vietnam is considered by many to be among the most vulnerable countries regarding coastal disasters and climate change (Thao et al., 2014). In the period of 1990–2018, Vietnam was hit by 86 storms, nearly 80 floods and other disasters such as landslides and droughts causing 12,522 deaths and total damage estimated at almost 22 billion US$ (EM-DAT, 2019). The most intense and destructive storm in recent history was the typhoon Linda, which caused the deaths of thousands of fishermen at sea in 1997. Roads, dykes and bridges were destroyed (Anh et al., 2017). The number of storms hitting Vietnam is predicted remain the same, while the number of the strong storms may increase by the end of this century (MONRE, 2016). More intense precipitation of tropical cyclones are also predicted to occur in the Southeast Asia (IPCC, 2013). This expected development creates a concern for the future of fisheries and other industries.

Martins and Gasalla (2018) published a study from the Southern Brazilian Bight on fishermen's perceptions of sea level changes, rainfall, wind, atmospheric temperature, coastal currents, wave action and extreme events such as large storms, drought and floods impacting marine resources and livelihoods of small-scale fishermen. From a Bangladeshi hilsa fishery, Jahan et al. (2017) made use of local knowledge to evaluate impacts of climate change, employing factors such as river erosion severity, salinity intrusion and cyclones and anthropogenic pressures (using factors such as overfishing, pirate attacks and sedimentation). These studies also compared fishermen's perceptions with time series on water temperature, rainfall and salinity intrusion to evaluate perceived changes in the light of registered variation. Fishermen's perceptions of social and economic problems, population density, disasters and climate change affecting coastal fishing communities in Bangladesh have also been investigated by Hasan and Nursey-Bray (2018).

In addition to mapping fishermen's perceptions of different environmental, economic and social factors, this study also aims to investigate possible differences between groups; for example between fishermen in different vessel groups to determine how perceived challenges are related to climate change. Does the perception of fishermen align with the scientific knowledge, and is climate change the biggest challenge of the fishery?

2. Data and methodology

A questionnaire was designed for the study that covered a number of known challenges for the fishermen. The fishermen's perceptions regarding environmental, biological and technological factors, as well as the socio-economic characteristics of the fishers, were evaluated according to five levels of impact: *severe problem*, *problem*, *no problem*, *advantage* and *significant advantage*. A clear distinction was also made between the fishermen's perceptions of the current situation (challenges and problems of today) and their expectations about the challenges in the future.

Climate change is a rather abstract idea and many are not able to differ between climate and weather. Therefore, we did not ask what the fishermen think about climate change. Instead, concrete problems like flooding, heavy rain, salinity intrusion into land areas, reduced fish prices, health risks, safety at sea and social issues were included. Socio-demographic information was also collected in the survey. Climate change perceptions and different adaptive strategies were also included in the questionnaire. A preliminary questionnaire was tested by eight experienced fishermen working in the Nha Trang purse seine fishery before the final questionnaire was completed.

The survey included 52 purse seine owners (they were also skippers, and all of them were males) selected from a population of 130 purse seiners registered at Khanh Hoa Department of Capture Fisheries and Resources Protection in Nha Trang in 2016 (DECAFIREP, 2016). The representativeness of the sample in terms of vessel hull length and engine horsepower is presented in Table 1. Data collection took place from December 2016 to March 2017 in three wards of Nha Trang: Vinh Nguyen, Hon Ro and Vinh Truong.

Table 1. Sample and population averages and standard deviations of selected vessel properties.

Variable	Sample size = 52		Population size = 130		t-Test statistics
	Mean	SD	Mean	SD	
Hull length	16.05	2.60	15.94	2.86	0.30
Engine power	303.10	163.27	300.35	173.29	0.12

SD: Standard Deviation

Data on rainfall between 2006 and 2019 and temperatures from 1990 to 2019 in Nha Trang were collected by HYSTSOCER (2015) and the General Statistics Office in Vietnam (GSO, 2020a, b). Statistics on natural disasters in Vietnam between 1990 and 2018 were obtained from the EM-DAT database in Belgium, while the capture production and engine capacity of the fishing fleet from 2009 to 2016 were reported by the General Statistics Office in Vietnam (GSO, 2020a), the Department of Agriculture and Rural Development (DEAGRUD, 2016) and the Khanh Hoa Department of Capture Fisheries and Resources Protection in Nha Trang in 2016 (DECAFIREP, 2016). The observed time series were analysed for linear trends using t-tests. Statistical analyses of variances (ANOVA) were performed to test whether there were differences in perceptions of changes in selected factors between or within the fishermen in different vessel groups. The fishermen's perceptions when comparing today's situation with the past (which is defined as five years back in time) are represented by three levels: 1 = worse, 2 = unchanged and 3 = better. While a period of five years may be too short to indicate significant trends, a longer period of time will exclude many in the sample. Therefore, a five-year perspective was chosen in spite of being a short timespan.

According to the classification of the Khanh Hoa Department of Capture Fisheries and Resources Protection, the Khanh Hoa fishing fleet is separated into small-scale vessels (vessels with engines less than 90 hp) and large-scale vessels (vessels with engines larger than 90 hp)

(DEAGRUD (2016)). Similarly, in this study the purse seine fishing fleet was divided into four groups on the basis of engine size. The group with the smallest engines included vessels with less than 90 hp (11.5% of the fleet). The next group included vessels with engines between 90 hp and 250 hp (26.9%), the third group included vessels with engines between 250 hp and 400 hp (28.9%) and the last group included vessels with engines larger than 400 hp (32.7%). The null hypotheses was that there were no differences in the perceptions of expected changes in the selected environmental, social and economic factors over time between or within the vessel groups.

In this study, when performing the ANOVA analysis, we used the Dunnett statistical test. With equal variance assumed, the null hypothesis was no the mean difference in the perceived changes in selected factors between or within the fishermen in different vessel groups. This null hypothesis will be rejected if the P-value of the mean group difference is less than the significance level of 5%.

Storms in Vietnam have been monitored for many years and are registered by the EM-DAT database in Belgium (see Figure 1). On average, each year three storms and tropical cyclones hit Vietnam. During the period of 1990–2018 the maximum number of storms occurred in 2000 when seven storms hit Vietnam while several years only included one storm. As shown in Figure 1 there is no trend in the registered number of storms and tropical cyclones in Vietnam during the monitored period.

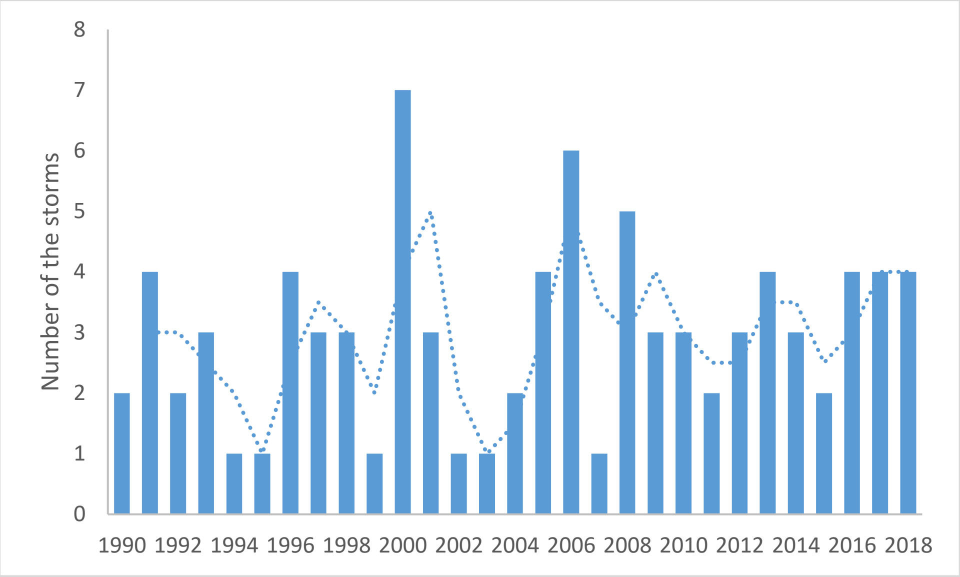

Figure 1: Registered storms in Vietnam during 1990–2018. The dotted curve shows the moving average. Source: The EM-DAT database in Belgium.

A slight upward sloping trend may be obtained for observed flooding since 1990. A linear model only explains 18.6% of the observed changes (Figure 2), and the changes may be due to random variations.

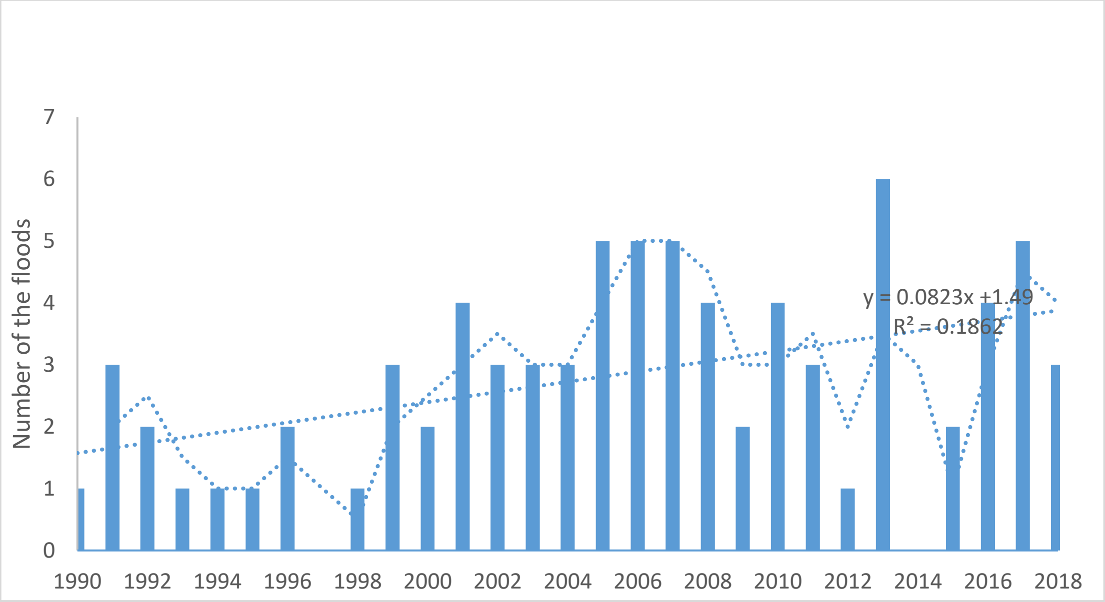

Figure 2: The floods in Vietnam during 1990–2018. The dotted line is a trend line, the dotted curve is a moving average and the corresponding results are from a linear regression. Source: The EM-DAT database in Belgium

Vietnam's annual rainfall is between 1,400 mm and 2,400 mm (MONRE, 2010). Nearly 80–90% of the total rainfall occurred during the rainy season, causing floods and landslides (Chaudhy and Ruysschaert, 2007).

As seen in Figure 3, the total amount of rain in Nha Trang shows no significant trend during the period of 2006–2019, with a minimum level of 819 mm in 2006 and a maximum level of 2,658 mm in 2010.

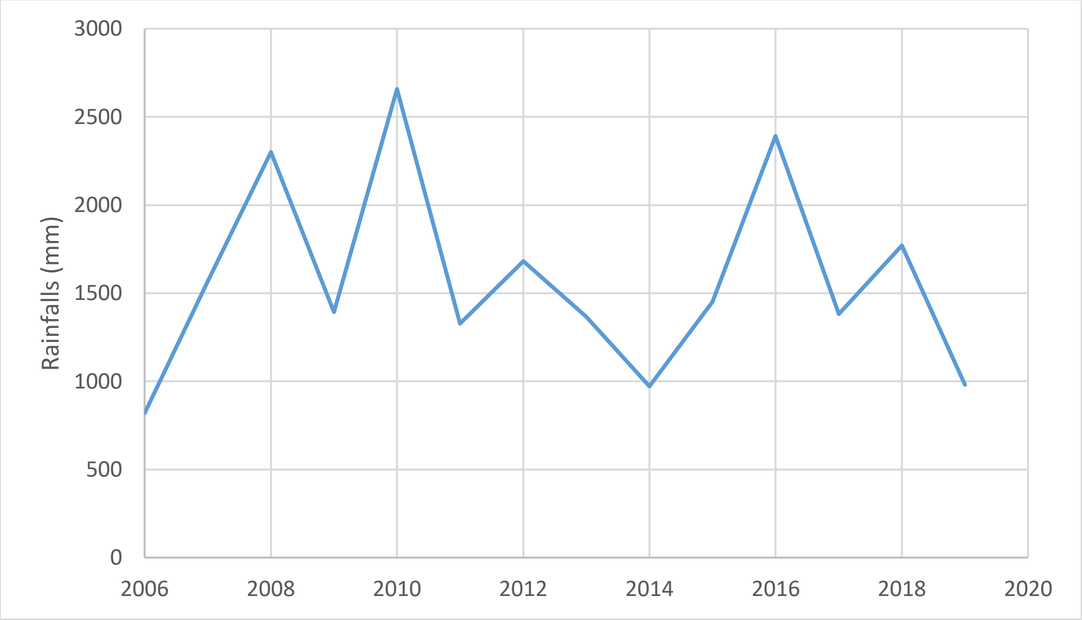

Figure 3: Rainfall in Nha Trang during 2006–2019. Source: (GSO, 2020c)

With a tropical monsoon climate, Vietnam's annual mean temperature varies from 18 ^{0}C to 29 ^{0}C (MONRE, 2016). The period of 1990–2019 shows a significant increasing trend in mean temperature and the linear model explains more than 50% of the increase (Figure 4).

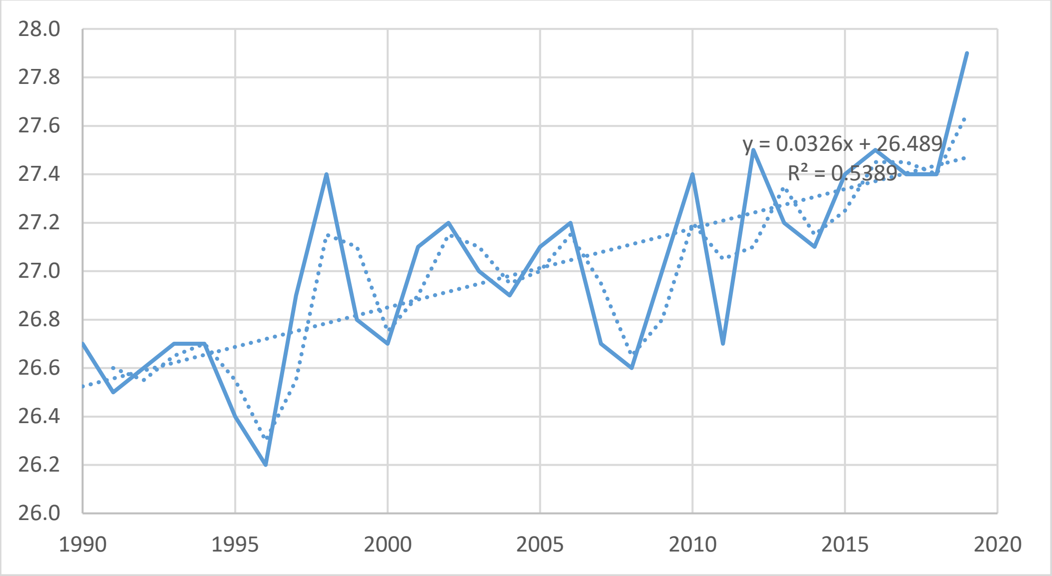

Figure 4: The temperature in Nha Trang during 1990–2019. A trend line is included (dotted line) and the results of the linear regression. Source: HYSTSOCER (2015) and GSO (2020b)

Registered catches showed an increasing trend, from 74,356 tonnes in 2009 to 92,753 tonnes in 2016 (Figure 5). A decline in the resource base may be reflected in a corresponding decline in the catch per hp, from 0.181 tonnes per hp to 0.168 tonnes per hp (see Figure 6).

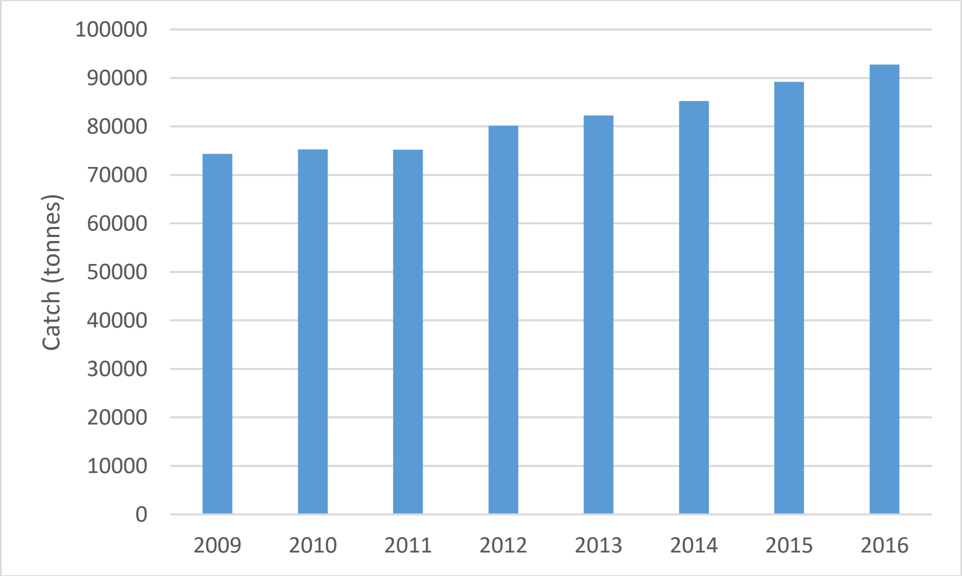

Figure 5: Marine production of Khanh Hoa fisheries during 2009–2016. Source: GSO (2020a).

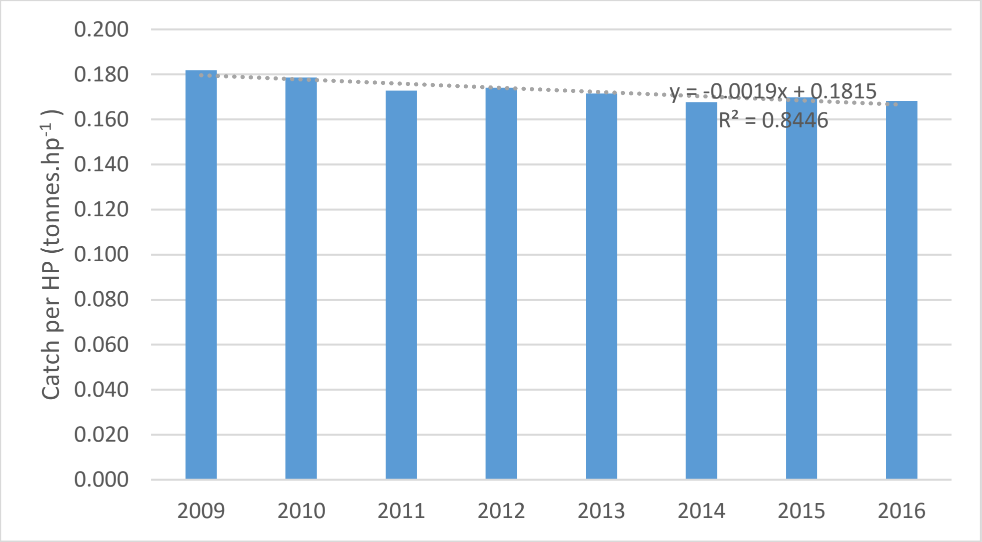

Figure 6: Catch per hp of Khanh Hoa fisheries during 2009–2016. The decreasing trend of catch per hp is indicated by the dotted line. The linear model explained 84% of the decline. Source: DEAGRUD (2016); DECAFIREP (2016); GSO (2020a).

3. Results

The fishermen in the sample were asked about their perception of the current situation in the fishery. Their answers showed that fishermen in the Nha Trang purse seine fishery have several concerns that are summed up in Figure 7, which shows that 12 out of 22 different factors are believed to affect their fishing activities.

Environmental factors, such as heavy waves, bad weather, storms/cyclones, severe floods, heavy rain and increasing temperature, are factors considered to have negative impacts on fishing activities. All fishermen expressed that storms have the most serious negative impact on their current production process because they may lead to boats capsizing, loss of fishing gear and even loss of lives (Figure 7). During the storm season, this fishing fleet stays in the harbour and there is no income. Some of the fishermen borrow money from the middle sellers in return for fish when their fishing operations commence again.

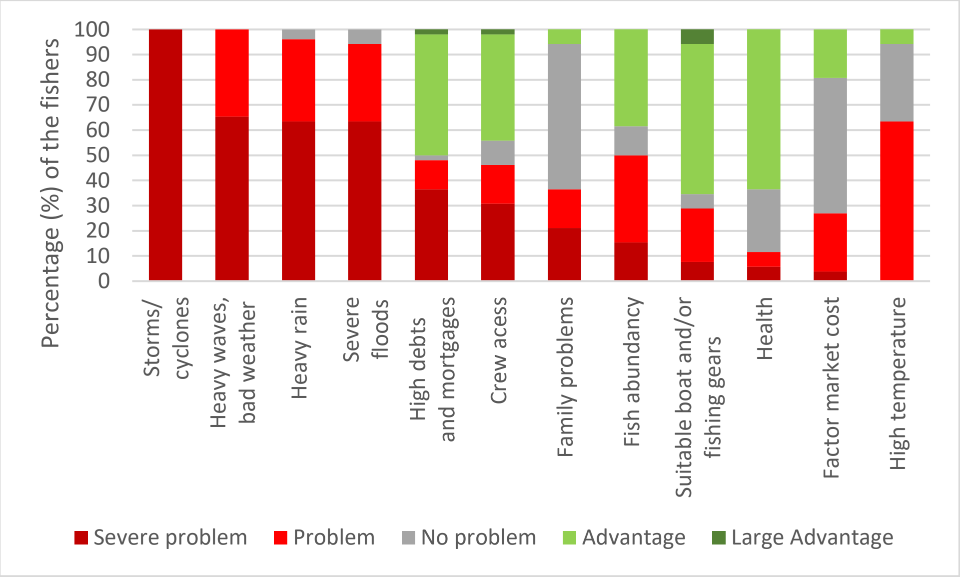

Figure 7. Fishermen's perceptions of selected factors currently affecting fishing activities.

When comparing today's situation with the past, all fishermen stated that storms and cyclones today represent a bigger problem than in the past (see Figure 8). The fishermen's perceptions of increased problems of storms and tropical cyclones in Vietnam are not supported by observations. However, our observations do not include the strength of storms and precipitation intensity. When a typhoon passes, it brings high tide, large waves and heavy rain that may result in flooding.

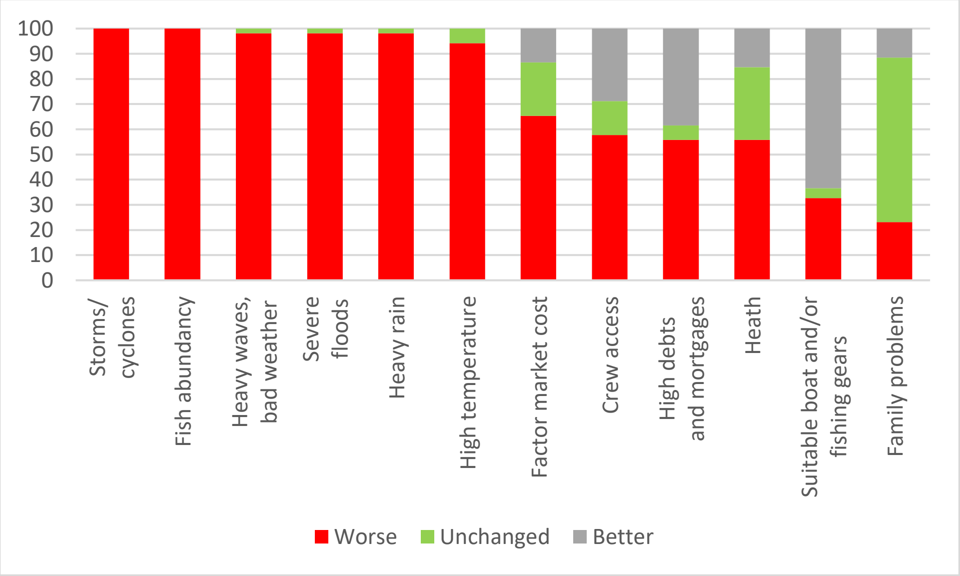

Figure 8: Fishermen's evaluations of today's problems compared with the past (five years ago).

As shown in Figure 7, nearly 65% of the fishermen claimed that floods and heavy rain are severe issues today. More than 95% of the fishermen are of the opinion that these problems have increased (see Figure 8). This is not supported by recent observations of floods and rainfall.

About 65% of the fishermen expressed that high temperatures also affect current fishing activity. More than 95% of the fishermen stated that the temperatures today are higher than in the past. This result is supported by the data.

The fishermen were divided when it came to stock abundance; 50% found it to represent a problem while almost 40% regarded it to be an advantage. Local differences in stock abundances could explain such differences, or it may reflect different expectations or interpretations of the same situation. However, compared with the situation five years ago, all of the fishermen agreed that the stock has decreased. According to their perceptions, the poor fish stocks may be a result of overfishing (possibly by the use of illegal fishing methods such as the use of explosives) and sea pollution.

Regarding economic factors, only about 25% of the fishermen claimed that markets represent a problem today. About half of the fishermen have problems related to capital availability, debts and mortgages when investing in fishing activities (see Figure 7).

About 65% of the fishermen stated that the cost of fishing has increased over the last five years (Figure 8). Although the price of fuel was reduced by 30% in 2016 compared with 2012, the prices of other inputs used in the production process, such as ice and other consumables, have increased over time.

Forty percent of the fishermen expressed that their debts now are higher than before since they recently borrowed substantial sums of money to invest in large vessels and new fishing gear. On the other hand, more than one-tenth of the surveyed fishers stated that because of a lack of mortgages they cannot open formal loans in commercial banks. However, nearly 50% said that it is an advantage. Some reasons for this explanation include that they do not want to borrow money from the bank because they feel that their current capital is fine for their production operation; they possess the collaterals so that they can get formal loans from commercial banks; and finally, their fishing activities earned positive profits in the studied year so that they have repaid the loans to the banks.

Figure 7 shows that almost 70% of the fishermen had modern and suitable boats and gear, while 30% worried about their fishing performance and safety at sea due to the old and small vessels. More than 60% of the fishermen claim to have better vessels today than five years ago (Figure 8).

When it comes to social factors, 36% of the fishermen found that factors related to their family situation, such as children and number of dependents (elders and the disabled), caused difficulties for their fishing activity. More than half of the sample complained of health problems due to climate change (warmer climate) and because fishing often takes all the night, starting at 4 pm and finishing at 8–9 am the following day. In addition, 40% of the fishermen claimed to have difficulties in getting crews for fishing trips. Most of the fishermen have low educational levels, with an average of six years in school, while about 80% of households depend on fishing.

When comparing selected factors affecting fishing activities today with the situation five years ago, some factors appear to be evaluated differently in the four vessel groups. An analysis of variance (ANOVA) showed significant differences (at a 5% significance level) in the perceptions of fish market development (prices), the suitability of boats and fishing gear, harbour conditions, security and crew access between vessel groups. The perception of the fish prices differs particularly between the smallest and largest vessel groups, reflecting a reduction in prices obtained by the small vessels, while the large vessels experienced increased fish prices over the past five years. These two groups also differ when it comes to the perception of boat suitability and the suitability of fishing gear. All fishermen in the smallest vessel group (less than 90 hp) stated that their vessels were older and smaller than other purse seiners in the region. The smallest vessel group also experienced more difficulties than others in getting crews (see the appendix), and they experienced difficult harbour conditions such as thefts when anchoring the vessels in the Hon Ro and Vinh Truong harbours.

Regarding the statement of climate change (see Figure 9), more than half of the fishermen perceived that climate change is occurring and impacts their fishing operations as well as influences their family lives. More than 65% of the fishermen disagreed that climate change is the local authorities' concerns, not theirs, and they also disagreed that it perhaps does not represent any major challenge for authorities and fishermen. In this sample, about 40% of the fishermen agreed that the government has prompt solutions to post-disasters, and 50% of the fishermen had no answers for this statement.

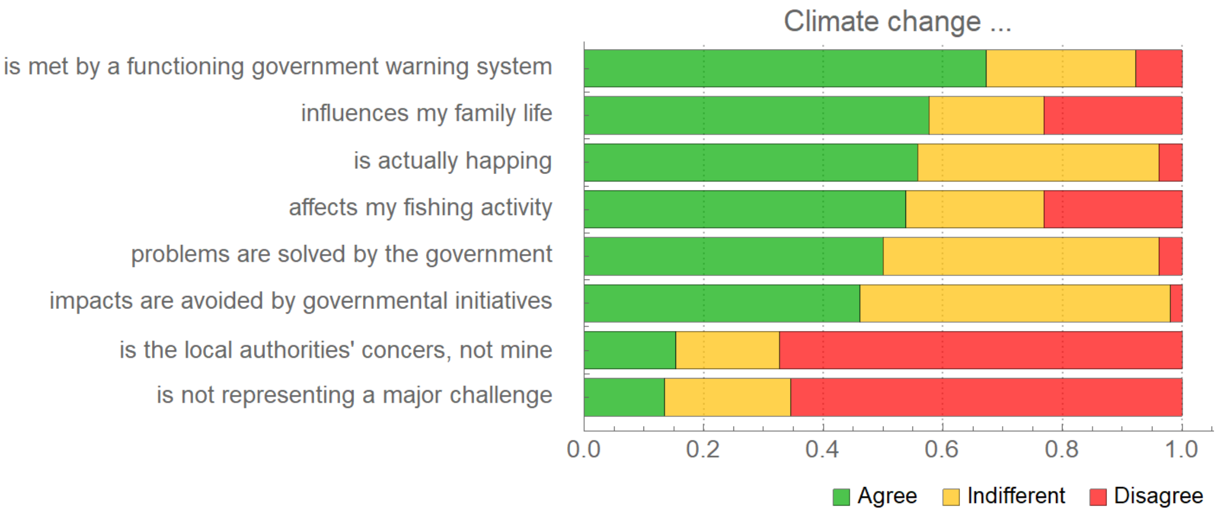

Figure 9: The 52 fishermen’s responses to the climate change statement.

The fishermen were also questioned about expected future impacts of selected factors affecting fishing activities (see Figure 10). The findings tend to be very similar to the answers obtained when comparing the current situation with the past. About 60% of the fishermen stated that they expect a further decline in fish abundance and more than 90% of the fishermen expected fishing costs to increase. Meanwhile, fishermen expected fish prices to increase in the future.

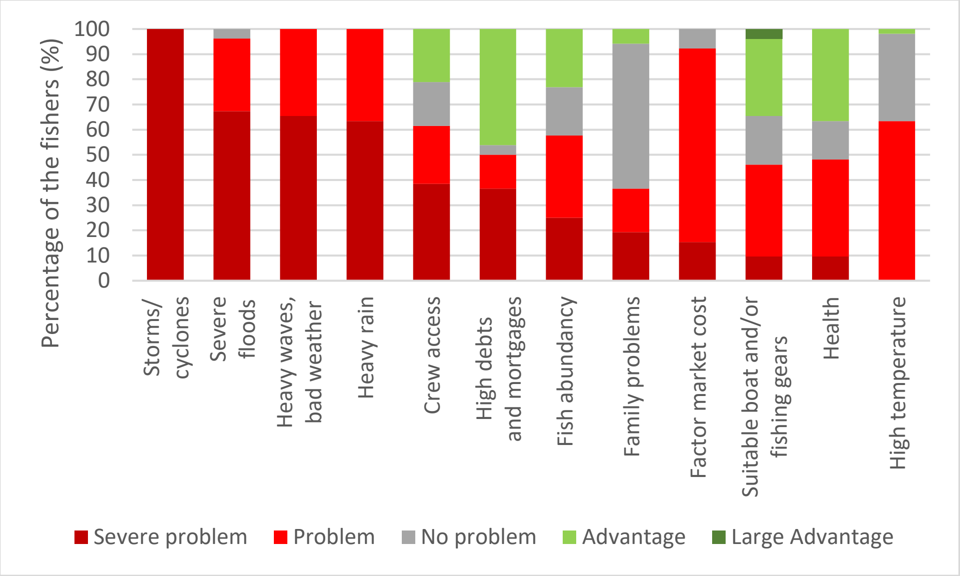

Figure 10: The sample's (all groups) evaluation of the impact selected factors have on future fishing activities.

The difference between the mean values of the current and future situations was calculated and is shown in Table 2. The findings show that climate change is not expected to be among the negative factors in the future. Future changes are expected in factors such as market cost, health, suitability of boats and/or fishing gear, crew access and fish abundance. These factors seem to worry the fishermen the most with respect of fishing activities in the future.

Table 2: Investigated factors believed to affect future fishing activities. The numbers give the differences between the mean values of the current and future situations after operationalising the answers by numbers (1 = severe problem, 2 = problem, 3 = no problem, 4 = advantage and 5 = large advantage). Factors that are expected to develop negatively are indicated by red colour and positive developments are indicated by green colour. No changes are expected for the blue factors.

Investigated factors	**Mean values**
Factor market cost	-0.9615
Health	-0.6731
Suitability of boats and/or fishing gear	-0.5192
Crew access	-0.4808
Fish market (price)	0.3654
Fish abundance	-0.3269
Security and legal conditions for fishing	-0.2115
Bycatch	-0.1731
Harbour conditions	0.1538
Competition among fishermen	-0.0962
Distance to fishing grounds	-0.0769
Capital availability, debts and mortgage	-0.0769
Severe floods	-0.0577
Safety at sea	-0.0577
High temperature	-0.0385
Heavy rain	-0.0385
Family problems affecting fishing activities	0.0192
Confidence in cooperating partners (crew/buyers/etc.)	0.0000
Salinity intrusion to land areas	0.0000
Sea level rise	0.0000
Storms/cyclones	0.0000
Heavy waves, bad weather	0.0000

4. Discussion

The purse seine fishermen perceived heavy waves, bad weather, storms/cyclones, severe floods, heavy rain and increasing temperatures to be factors negatively affecting fishing activities. Storms and tropical cyclones may cause boats to capsize, loss of fishing gear and even loss of lives.

Floods and heavy rains disrupt fishing activities. However, the fishermen's perceptions of increased storms do not match the data. It could be due to differences between regions not covered by national statistics, or it may reflect misperceptions. Also, in the case of flooding, the fishermen's perceptions of increased problems are not in line with the data, but may be explained by local variations. Alternatively, the natural level of flooding could appear as more problematic due to changes in fishing methods, fishing areas or fishing seasons.

The fishermen's perceptions of increased rainfall also does not match observations. There may be more heavy rain than before, but the quantity of rain has not changed. Unfortunately there are no statistics to verify this. For example, 57 fishing vessels were reported to have sunk or become damaged in 2016 close to the river mouth because of flooding caused by heavy rain in the Nha Trang area (BNEWS, 2017).

The findings presented here correspond with other studies of fishermen's perceptions of increased atmospheric temperature in the South Brazilian Bight and coastal Bangladesh (Jahan et al., 2017; Martins and Gasalla, 2018). Fishermen working in the South Brazilian Bight fishery perceived that the increased temperature benefitted their livelihoods because it improved the catches as well as the production of mussels, oysters and seaweed. However, if the water becomes too warm, the impact will be negative, as it can hinder production (Martins and Gasalla, 2018). For rainfall, a study by Hasan and Nursey-Bray (2018) showed that fishermen were more concerned about the increased rainfall on coastal Bangladesh, which is in contrast to fishermen's perceptions in the South Brazilian Bight fishery (Martins and Gasalla, 2018) where they perceived that the rainfall has decreased significantly over time and negatively impacted their livelihoods due to a shortage of fresh water, catch reductions and crop losses.

The poor fish stocks may be due to overfishing or changing environmental conditions. Compared with some fisheries in Bangladesh, respondents from the studies of Jahan et al. (2017) and Hasan and Nursey-Bray (2018) were also very concerned about the increased intensity of fishing and overfishing because coastal small-scale fishermen are highly dependent on the fisheries. They also claimed that overfishing, increased disasters and sea pollution are some of the causes of the decline in fish stocks.

However, almost half of the fishermen in our sample did not find fish abundance to be a potential problem in the future; all of them claimed it is worse than before. There may be different reasons for this: 1) Although the fish stocks have declined, many fishermen have invested in large vessels and modern fishing equipment in order to access fishing grounds further out where fish are more abundant. 2) The fishermen expect new fish species to be available for exploitation and that increasing fish prices will substitute possible declines in catches.

Recently, the fishermen purchased larger vessels and better equipment but they experienced bigger problems from storms and heavy rain. There may be some reasons to explain this. The main engines of the vessels were broken before travelling to safe places to avoid the storms. They are fishing in more exposed areas although they receive information on the direction of storms from the authorities. Also, at that time they had to spend longer times at sea because of the approaching waves and winds. In addition, heavy rain and storms create problems of performing fishing operations. Finally, fishermen dock their vessels close to the river mouth, causing vessel damages or losses in instances of severe floods. Fishermen also have to work harder when going to the fishing grounds further out, such as in Quang Ngai, Phan Thiet, Binh Thuan and Ca Na provinces, due to the decline in local stocks. The fishing period has been also extended and fishing now takes place in seasons not previously utilized.

Fishing boats have become larger in the last five years but fishermen in the sample are worried about the suitability of their boats and fishing gear for future fishing activity. This may be due to fear of overexploitation of coastal fish resources. They need to have larger vessels to go to the further fishing grounds where fish are more abundant, but they must face the difficult weather conditions there. There is a great need for the capital to invest in building new and large vessels. However, they cannot access formal loans because of a lack of collateral. In addition, fishermen are afraid of the complicated administrative processes when they borrow large amounts of money from banks. Moreover, they are also afraid that they will not be capable of repaying the loans to the banks when the landings may be lower in the future (because of the decline in the fish stocks). Therefore, they are worried about the suitability of boats in the future if they still use their current vessels to continue fishing

Regarding the family issues, many fishermen in the sample moved to the mainland from islands to live. They believe that their lives are better there because their children can access better schools and medical care services. Moreover, in most Vietnamese families, men earn the main income while women take care of the children and take care of the household. Therefore, fishermen are not worried about family issues and only focus on their fishing activities. However, according to Vietnamese culture, fishing experience is passed down from generation to generation. Therefore, they hope that their sons will follow in their fishing career if they cannot continue to go to the school. However, fishing takes all night with warmer climate, so they are concerned about their physical health as they age.

More than 50% of the fishermen in the sample were concerned about crew access in the future. This can be explained by several factors. Fishing activities are fluctuating and may require seasonal labour to be attracted from other parts of the country. This labour often requires higher wages than the local labour. In addition, fishing requires a large number of labourers to work on the boats. A fishing trip cannot be performed if there are not enough labourers working on the purse seine vessels. If vessels become economically inefficient, this can cause them to become worried much more about getting a crew.

Almost all fishermen working the large vessels perceived that climate change is happening and impacts their fishing activity and influences their families' lives. They also found that the governmental disaster warning system is working well. In the future, tropical cyclone and typhoon occurrences in Vietnam are expected to change under climate change scenarios, as they may become more intense or change patterns of storm tracks (MONRE, 2016). To reduce the risks to their operation, all fishermen in the sample followed weather forecasts/warnings (on television and radio) before going out to fish. In addition, they equipped their boats with modern communication equipment to contact their neighbours' vessels, the authorities and the rescue team when their vessels encounter problems at sea (e.g., broken machines, accidents). Moreover, fishermen attended the insurance system to mitigate shocks from natural disasters. They will have the initial capital to buy nets, boats and other fishing materials after natural disasters. However, they have many difficulties with the administrative procedures when doing refunds with their insurance. Along with these adaptive strategies, to develop fisheries sustainably and help fishermen have the sustainable livelihoods, we suggest that the fishermen start other activities for sources of income. The fishermen also hope that the government will solve all problems after disasters. This study suggests that the public should accommodate other business opportunities to promote sustainable livelihoods.

The fishermen in general are more concerned about changes in market and prices, health, harbours, suitability of boats and gear, crew access, etc., than storms and bad weather, flooding, heavy waves and other environmental risks. The fishermen seem to emphasize factors that they may control to a certain degree (cost of fishing, suitability of boats and gear, crew access, health) and place less emphasis on factors beyond their control. No fishing takes place in periods of heavy rain and storms. During the storm season (the last three months of the year) fishing vessels stay at shore. Fishing activities are expected to be affected by climate change. An increase in cyclonic activities in the fishing area may cause interrupted fishing trips leading to significant income and investment losses.

This study considers events and possible changes that could severely affect these communities. What are the fishermen's perceptions of different events and how are they able to cope with expected changes? The fishermen's answers may reflect that the survey represents a chance to complain and to deliver messages that are difficult to express through other channels. Their answers may also hide hopes of future governmental support and wishes of having some impact on future management decisions.

5. Conclusion

This paper studied fishermen's perceptions of how environmental events and social-economic factors influence fishermen and their activities. This empirical study focused on 52 fishermen working in the Vietnamese purse seine fishery. The findings showed that heavy waves, bad weather, storms/tropical cyclones, high temperatures, heavy rains, varying fish abundancy, high costs of fishing, the poor availability of capital, health and crew access are the factors that negatively affect fishing activities. Uncertainties related to these factors are the main problems and concerns for their current fishing activities. This paper also showed that fishermen's perceptions of increased temperature and declined fish stocks are correlated with the availability of the data. Otherwise, fishermen's perceptions of increased problems from storms/tropical cyclones, floods and heavy rain do not march the observations. This may be due to misperception or differences between regions not covered by national statistics or random variation (e.g., local variation). Almost all of the surveyed fishermen expect that climate change will not be among the negative factors in the future. Meanwhile, fishermen are worried about the future suitability of fishing gear and boats, fish stock development, the cost of fishing, health problems and crew access. These are the factors that fishermen are concerned about when reflecting upon their fisheries in the future.

Climate change is affecting Vietnam and it disrupts fishing activities and influenced fishermen’s lives and livelihoods today. With weather conditions set to become both more extreme and unpredictable, the problem will become even more pronounced in the future. Climate change is expected to bring increased disaster risk to this tropical country, including changes in precipitation, typhoons, floods and temperature. Therefore, it is necessary to increase the fishermen’s knowledge and awareness about the threats caused by the natural disasters as well climate change’s impacts now and in the future. This can help them with adaptive strategies to reduce or cope with these impacts on time. However, fishermen are usually and by nature rather adaptive, and adaptive on a different time scale than the time scale climate change operates on.

There may be local differences regarding the issues studied in this paper. The sample data for this study is not biased when compared to the market-based data. The fishermen’s answers may also reflect complaints and messages that are difficult to express through other channels. The expressed answers may also hide hopes of future governmental support and will possibly have some impact on future management decisions.

Appendix: Testing the differences in perceptions of the changes in the selected factors between the four vessel groups, 1–4: Group 1 includes vessels with less than 90 hp ($n_1 = 6$); Group 2, vessels with engines between 90 hp and 250 hp ($n_2 = 14$); Group 3, vessels with engines between 250 hp and 400 hp ($n_3 = 15$); and Group 4, vessels with engines larger than 400 hp ($n_4 = 17$).

Dependent Variable	Cross-reference Group 4 vs Group	Mean group Difference	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Heavy rain, bad weather	1	0.000	0.066	1.000	-0.16	0.16
	2	0.000	0.050	1.000	-0.12	0.12
	3	0.067	0.049	0.419	-0.05	0.19
Severe floods	1	0.000	0.066	1.000	-0.16	0.16
	2	0.000	0.050	1.000	-0.12	0.12
	3	0.067	0.049	0.419	-0.05	0.19
Heavy rain	1	0.000	0.066	1.000	-0.16	0.16
	2	0.000	0.050	1.000	-0.12	0.12
	3	0.067	0.049	0.419	-0.05	0.19
High temperatures	1	-0.059	0.115	0.928	-0.34	0.22
	2	0.013	0.087	0.998	-0.20	0.23
	3	0.008	0.086	1.000	-0.20	0.22
Sea level rise	1	0.118	0.140	0.756	-0.22	0.46
	2	0.118	0.106	0.577	-0.14	0.38
	3	-0.082	0.104	0.789	-0.34	0.17
Salinity intrusion to land areas	1	0.059	0.094	0.879	-0.17	0.29
	2	0.059	0.071	0.767	-0.12	0.23
	3	-0.008	0.070	0.999	-0.18	0.16
Fish price	1	-1.029*	0.378	0.025	-1.95	-0.11
	2	-0.387	0.287	0.421	-1.09	0.32
	3	-0.596	0.282	0.105	-1.29	0.09

Fishing cost	1	-0.480	0.349	0.402	-1.33	0.37
	2	-0.218	0.265	0.767	-0.87	0.43
	3	-0.180	0.260	0.844	-0.82	0.46
Capital availability, debts and mortgage	1	0.510	0.462	0.579	-0.62	1.64
	2	-0.181	0.351	0.927	-1.04	0.68
	3	-0.024	0.345	1.000	-0.87	0.82
Suitability of boats and/or fishing gear	1	-1.765*	0.383	0.000	-2.70	-0.83
	2	-0.479	0.291	0.261	-1.19	0.23
	3	-0.431	0.286	0.328	-1.13	0.27
Family problems	1	-0.618	0.266	0.066	-1.27	0.03
	2	-0.403	0.202	0.135	-0.90	0.09
	3	-0.184	0.198	0.698	-0.67	0.30
Health	1	-0.598	0.355	0.244	-1.47	0.27
	2	-0.122	0.270	0.949	-0.78	0.54
	3	-0.231	0.265	0.735	-0.88	0.42
Crew access	1	-1.118*	0.397	0.020	-2.09	-0.15
	2	-0.689	0.302	0.073	-1.43	0.05
	3	-0.318	0.296	0.601	-1.04	0.41
Harbour conditions	1	-1.020*	0.305	0.005	-1.77	-0.27
	2	-0.067	0.232	0.985	-0.63	0.50
	3	0.114	0.228	0.933	-0.44	0.67
Distance to fishing grounds	1	0.176	0.287	0.884	-0.52	0.88
	2	-0.252	0.218	0.543	-0.78	0.28
	3	-0.224	0.214	0.620	-0.75	0.30
	1	-0.441	0.438	0.646	-1.51	0.63

Confidence in cooperating partners (crew/buyers/etc.)	2	-0.227	0.333	0.851	-1.04	0.59
	3	0.659	0.327	0.129	-0.14	1.46
Security and legal conditions for fishing	1	-0.657*	0.208	0.008	-1.17	-0.15
	2	-0.324	0.158	0.121	-0.71	0.06
	3	-0.024	0.155	0.998	-0.40	0.36
Safe at sea	1	-0.529	0.365	0.361	-1.42	0.36
	2	-0.172	0.278	0.882	-0.85	0.51
	3	-0.263	0.272	0.675	-0.93	0.40

Acknowledgements

We wish to thank the Norhed project SRV-13/0010 for providing financial support for the data survey. We also are grateful for valuable input from Claire W. Armstrong, the Marine Resource Economics research group, and the committee at The Arctic University of Norway.

References

Anh, L.T., Takagi, H., Thao, N.D., Esteban, M. (2017). Investigation of awareness of typhoon and storm surge in the mekong delta – recollection of 1997 typhoon linda. Journal of Japan Society of Civil Engineers, Ser B3 (Ocean Engineering) 73: 168-173.https://doi.org/10.2208/jscejoe.73.I_168

BNEWS 2017. Khanh Hoa arranges anchorage for fishing boats during the rainy and storm season https://bnews.vn/khanh-hoa-sap-xep-cho-neo-dau-cho-tau-ca-trong-mua-mua-bao/54045.html. (Accessed 09 December 2020).

Cao, N.T.H., Eide, A., Armstrong, C.W., Le, L.K. (2021). Measuring capacity utilization in fisheries using physical or economic variables: A data envelope analysis of a Vietnamese purse seine fishery. Fisheries Research 243: 106087.https://doi.org/https://doi.org/10.1016/j.fishres.2021.106087

Chaudhy, P., Ruysschaert, G. 2007. Human Development Report 2007/2008: Fighting climate change: Human Solidarity in a divided world, Climate change and human development in Vietnam. United Nations Development Programme (UNDP), New York. 3 pp.

DEAGRUD 2016. Master plan for Khanh Hoa fishery sector during 2016-2025 and orientation for year 2035 (Quy hoạch phát triển ngành thủy sản tỉnh Khánh Hòa giai đoạn 2016-2025 và định hướng đến năm 2035). (In Vietnamese). Khanh Hoa's Department of Agriculture and Rural Development (DEAGRUD), Vietnam. 27 pp.

DECAFIREP 2010. The annual report of the number of vessels and engine power registered in 2010. Khanh Hoa's Department of Captures Fisheries and Resource Protection (DECAFIREP), Vietnam.

http://snnptntkh.gov.vn/news/us/dep/news_detail.aspx?id=202001101705232099756.48&idDV=0.5.

DECAFIREP 2016. The annual report of the number of vessels and engine power registered in 2016. Khanh Hoa's Department of Captures Fisheries and Resource Protection (DECAFIREP), Vietnam. http://snnptntkh.gov.vn/news/us/dep/news_detail.aspx?id=202001101705232099756.48&idDV=0.5.

EM-DAT 2019. Vietnam's disasters. https://data.humdata.org/dataset/emdat-country-profiles#metadata-0. (Accessed 01 July 2019).

GSO 2018. Statistical yearbook of Vietnam 2018. Production of fishery in Vietnam. Statistical Publishing House, G.S.O.G., Ha Noi, Vietnam. https://www.gso.gov.vn/en/px-web/?pxid=E0651&theme=Agriculture%2C%20Forestry%20and%20Fishing. (Accessed 28 October 2020).

GSO 2020a. Statistical yearbook of Vietnam 2020. Production of fishery caught by Khanh Hoa province. Statistical Publishing House, G.S.O.G., Ha Noi, Vietnam. https://www.gso.gov.vn/en/px-web/?pxid=E0654&theme=Agriculture%2C%20Forestry%20and%20Fishing. (Accessed 09 December 2020).

GSO 2020b. Statistical yearbook of Vietnam 2020. Mean air temperature in Nha Trang. Statistical Publishing House, G.S.O.G., Ha Noi, Vietnam. https://www.gso.gov.vn/en/px-web/?pxid=E0112&theme=Administrative%20Unit%20and%20Climate&subtheme=Mean%20air%20temperature%20at%20some%20stations. (Accessed 21 October 2020).

GSO 2020c. Statistical yearbook of Vietnam 2020. Total rainfall in Nha Trang. Statistical Publishing House, G.S.O.G., Ha Noi, Vietnam. https://www.gso.gov.vn/en/px-web/?pxid=E0107&theme=Administrative%20Unit%20and%20Climate. (Accessed on 21 October 2020).

Hasan, Z., Nursey-Bray, M. (2018). Artisan fishers' perception of climate change and disasters in coastal Bangladesh. Journal of environmental planning and management 61: 1204-1223.https://doi.org/10.1080/09640568.2017.1339026

HYSTSOCER 2015. The report of mean air temperature in Nha Trang during 1990-2014. The Hydrometeorological Station of the South Central region (HYSTSOCER), Vietnam. http://kttvntb.gov.vn/Contact.aspx.

IPCC 2013. Climate change 2013: The physical science basis. Working group I contribution to the fifth assessment report of the intergovermental panel on climate change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 100 pp.

Jahan, I., Ahsan, D., Farque, M.H. (2017). Fishers' local knowledge on impact of climate change and anthropogenic interferences on Hilsa fishery in South Asia: evidence from Bangladesh. Environment, Development and Sustainability 19: 461-478.https://doi.org/10.1007/s10668-015-9740-0

Martins, I.M., Gasalla, M.A. (2018). Perceptions of climate and ocean change impacting the resources and livelihood of small-scale fishers in the South Brazil Bight. Climatic Change 147: 441-456.https://doi.org/10.1007/s10584-018-2144-z

MONRE. 2010. Vietnam's second national communication to the united nations framework convention on climate change. Minister of Natural Resources and Environment (MONRE), Ha Noi, Vietnam. 14 pp.

MONRE 2016. Climate change and sea level rise scenarios for Vietnam (Kịch bản biến đổi khí hậu và nước biển dâng cho Việt Nam). In Vietnamese. Natural Resouces, Environment and Cartography (NARENCA), Ha Noi, Vietnam. https://vihema.gov.vn/wp-content/uploads/2015/12/03.-Tom-tat-Kich-ban-BDKH-va-NBD-cho-VN_2016_Tieng-Viet.pdf.

Nga, C.T.H., Eide, A., Armstrong, C.W., Long, L.K. (2020). Economic performance and capacity utilisation in Vietnamese purse seine fishery. Asian Fisheries Science 33: 58-64.https://doi.org/https://doi.org/10.33997/j.afs.2020.33.1.007

Pomeroy, R., Kim Anh, N.T., Thong, H.X. (2009). Small-scale marine fisheries policy in Vietnam. Marine Policy 33: 419-428.https://doi.org/10.1016/j.marpol.2008.10.001

Thao, N.D., Takagi, H., Esteban, M. 2014. Coastal disasters and Climate change in Vietnam: Engineering and planning perspectives. Elsevier, London and US. https://books.google.com.vn/books?id=qrtCAgAAQBAJ&printsec=frontcover&dq=Coastal+disasters+and+Climate+Change+in+Vietnam.+Engineering+and+planning+perspectives&hl=vi&sa=X&redir_esc=y#v=onepage&q=Coastal%20disasters%20and%20Climate%20Change%20in%20Vietnam.%20Engineering%20and%20planning%20perspectives&f=false.

Vasep. 2018. Whitebook on combating IUU fishing in Vietnam. Vietnam Association of Seafood Exporters and Producers, Vietnam. http://seafood.vasep.com.vn/while-book-iuu.html.