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MANAGING SUSTAINABILITY AND EFFICIENCY: MARKET AND NON-MARKET VALUE APPROACHES IN MEDITERRANEAN FISHERIES

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ABSTRACT

This thesis contributes to natural resource management in Mediterranean fisheries by integrating market and non-market value perspectives, linking environmental and economic analyses. It emphasizes the necessity of quantifying the entirety of fisheries values while stressing the importance of efficient, sustainable resource management.

The first chapter scrutinizes the effectiveness of Fisheries Local Action Groups in steering sustainable development in maritime areas. Reviewing previous studies through the lens of Porter's Diamond, we explore how FLAGs influence coastal community competitiveness. The findings underscore potential implications for the adoption of Community-Led Local Development strategies, particularly within the European Maritime, Fisheries and Aquaculture Fund framework for 2021-2027.

The second chapter investigates the economic externality created by small-scale fishing ports. Using a travel cost approach, we assess the value that visitors place on recreational activities offered by these ports. Unveiling substantial consumer surplus from artisanal ports, this chapter highlights the potential of diversifying income sources for coastal communities and advocates for small-scale fishery sector support.

The third chapter focuses on vessels efficiency in the *rapido* fishery of Chioggia through stochastic frontier analysis and catch profile examination. By identifying fishing strategies with optimal performance in terms of revenue generation and carbon footprint, this chapter aims to improve efficiency in one of the most problematic segments of the Adriatic Sea's large-scale fleet.

Lastly, the fourth chapter extends the efficiency analysis by investigating price formation, seasonality effects, and price-quantity relationships for primary species targeted by *rapido* vessels. Examining fishers' tendencies towards revenue maximization, this chapter seeks to provide insights for fisheries management, emphasizing the need for adaptable approaches in the Mediterranean context.

Overall, this thesis aims to contribute to the ongoing discourse on the adaptability and flexibility required in managing Mediterranean fisheries, recommending more nuanced and responsive strategies in the face of dynamic market conditions and environmental challenges.

INTRODUCTION

1.1. General context

Fisheries are an essential component of many coastal communities around the world, providing food, employment, recreation, and cultural significance. However, in recent years the fishing sector has been facing numerous challenges, such as environmental degradation, overfishing and changing market dynamics. Understanding the market and non-market value of fisheries is crucial for sustainable management and development of these resources.

Mediterranean fisheries represent a relevant case study due to the complex interplay of socio-economic and environmental factors that threaten the sustainability of coastal economies. Given the state of overexploitation affecting numerous stocks in the Mediterranean Sea (FAO, 2022) and the increasing social pressures resulting from reductions in fishing effort (Márquez Escamilla et al., 2022), rising fuel costs (Guillen et al., 2023) and the lack of generational renewal (Penca et al., 2021), the chapters of this thesis advocate for a fisheries management approach that embraces an ecosystem-based perspective (Long et al., 2015; European Commission, 2023a), addressing both socio-economic and environmental considerations. This is reflected by the centrality of themes such as the efficient use of resources (Chapters III and IV), the potential for community-led local development in fisheries areas (Chapter I), the positive externalities of small-scale fisheries on coastal economies (Chapter II), the carbon footprint of large-scale fisheries (Chapter III) and the market opportunities to stabilize the level of fish prices (Chapter IV).

The diverse themes and discussions raised in this thesis hence provide a comprehensive overview of the fishing sector that closely aligns with the concepts of *multifunctionality* and *total economic value*. In particular, multifunctionality refers to the set of social, economic, and ecological functions that fisheries perform, beyond their role in providing food and income. This concept, originally applied to the agricultural domain, has become increasingly used also in the fishing sector (Ropars-Collet et al., 2017; Prosperi et al., 2019), especially with regard to the provision of material and immaterial goods by artisanal fisheries (Malorgio et al., 2017). Numerous categories of non-commodity outputs have been identified in fisheries, including cultural heritage, coastal employment and food security. Many of these outputs exhibit characteristics of externalities or public goods, justifying the need for fisheries management that ensures the socially optimal provision of these services (Mulazzani et al., 2019). Associated with the idea of multifunctionality, the concept of total economic value offers a comprehensive assessment of environmental goods by considering both their use and non-use values, which can be estimated using non-market valuation techniques (Ledoux and Turner, 2002), as in the case of recreational services provided by artisanal fisheries estimated through the travel cost method (Waldo et al., 2023). Multifunctionality and total economic value are further presented and investigated in Chapters I and II of the thesis, while Chapters III and IV mostly rely on methodologies making use of effort and market data to investigate the efficiency of fishing operations. Thus, this thesis adopts different methodological approaches (literature review, efficiency analysis, non-market valuation) to inspect Mediterranean fisheries from a broader perspective that encompasses both their monetary and non-monetary contributions to society. The four chapters collectively contribute to our understanding of the economic, environmental, and social dimensions of fisheries, and how these interact in the context of coastal communities.

1.2. Thesis structure

The first chapter investigates the role of Fisheries Local Action Groups (FLAGs) in the development of European coastal regions. FLAGs are partnerships between fisheries stakeholders and local authorities aimed at promoting a sustainable and integrated development of maritime areas. By means of a literature review, the chapter organizes the main findings from previous studies following the six dimensions of the Porter's Diamond in order to examine the impact of FLAGs on coastal communities' competitiveness. The results of this study are discussed in terms of implications for the future application of Community-Led Local Development (CLLD) strategies in the European Maritime, Fisheries and Aquaculture Fund (EMFAF) period 2021-2027.

The second chapter examines whether small-scale fishing ports represent a source of attraction for visitors engaging in recreational activities, thus providing a positive externality to the economy of European coastal areas. The study employs a travel cost approach, which estimates the value that visitors place on the recreational services provided by fishing ports. This analysis provides insights into the potential for coastal communities to diversify their income sources and benefit from the multifunctionality of fisheries. Moreover, as the results highlight the existence of a significant positive consumer surplus derived from the presence of artisanal fishing ports, the findings offer insights into the justification for financial support to the small-scale fishery sector, emphasizing the importance of understanding the societal benefits derived from fisheries.

The third chapter links stochastic frontier analysis with the multivariate study of catch profiles to estimate the technical efficiency of fishing vessels in the *rapido* fishery of Chioggia, which is one of the most problematic segments of the large-scale fleet in the Adriatic Sea. Stochastic frontier analysis is a statistical method for evaluating the efficiency of production processes, while catch profiles reflect the landings composition in terms of relevance of the different species over total catch. The study uses cluster analysis for the identification of distinct groups of fishing trips characterized by similar composition of landings and examines the relationship between these profiles and technical efficiency, in order to identify the fishing strategies with the best performance in terms of carbon footprint and generated revenue.

The fourth chapter extends the efficiency analysis of the previous chapter through the study of price formation, seasonality effects and price-quantity relation for the main species targeted by *rapido* vessels. Moreover, based on the estimated efficiency scores, the attitude of fishers towards value or weight maximization is examined, with the intent of providing practical management suggestions aimed at improving the profitability of the fishery while taking into account monthly fluctuations in fish market prices. In summary, this article contributes to the ongoing discussion about the need for more flexible and adaptable management approaches in European fisheries, especially in the Mediterranean context.

1.3. Policy relevance

In the domain of fisheries economics, it is imperative to align research efforts with the evolving landscape of European policies. The European Union has been actively engaged in shaping the future of fisheries through recent initiatives like the Farm to Fork and the Green Deal. As recalled by DG MARE, the specific objectives 1 and 2 of the Strategic Plan 2020-2024 ("More sustainable and competitive fisheries and aquaculture by 2024" and "A sustainable blue economy generating sustainable economic development, jobs and prosperity by 2024") are indeed specifically aimed at addressing the ambitions of the European Green Deal. Furthermore, the European Commission's recent communications, specifically COM (2023) 101, COM (2023) 102, and COM (2023) 103, highlight the key policy directions for the sustainable development of fisheries. These communications emphasize *i*) the importance of protection and restoration of marine ecosystems, to be addressed through improved gear selectivity and the reduction of trawlable areas while securing a fair and just transition for all actors in the sector; *ii*) the multifunctionality of fisheries, recognizing their economic, social, and cultural significance, and calling for a transition towards a more efficient, sustainable, science-based, and inclusive sector; *iii*) the need to update the Common Market Organization through the promotion of Producer Organisations establishment, the inclusion of sustainability standards in the marketing of fish products and the role of consumer information, thus favoring synergies with the Farm to Fork strategy. By addressing these policy themes, the thesis contributes to the broader conversation surrounding the future of European fisheries, aligning our research with the goals of these pivotal policy documents for the promotion of sustainable fisheries management.

Moreover, it is essential to link the above-mentioned documents to a broader European Union policy orientation aimed at strengthening sustainability and resilience not only within the fisheries sector but also across the management of natural resources as observed, for instance, in the context of the Common Agricultural Policy (CAP) (Galán et al., 2022). Concerning marine living resources, the imperative to enhance the performance of European fishing systems across the triad of sustainability dimensions- encompassing social, economic and environmental aspects- has been indeed articulated in various policy directives belonging to the European Green Deal. Specifically, these directives include the EU Biodiversity Strategy for 2030, the Farm to Fork Strategy, and the Circular Economy Action Plan. These policy instruments advocate for the uptake of increased sustainable practices in the fishing sector, for instance through the maintenance of fishing mortality at or below Maximum Sustainable Yield (MSY), the prevention of illegal, unreported, and unregulated fishing, and the mitigation of marine plastic pollution stemming from fishing gear (European Commission, 2020a; European Commission, 2020b; European Commission, 2020c).

Overall, this thesis attempts to address the impellent policy discussions presented above by providing a comprehensive analysis of fisheries economics from a multifunctionality perspective[1]. It endeavors to bridge the divide between the market-driven aspects of the fishing industry and the often intangible, non-market values that coastal communities place on fishing activities and their interactions with surrounding ecosystems. Sustainability considerations underpin every facet of this research, whose intention is to contribute to the enduring vitality of marine resources and the communities reliant upon them. By investigating the market and non-market value of fisheries, the thesis broadens our understanding of the economic, social, and environmental significance of these resources. The results of these studies can inform policy decisions aimed at promoting sustainable fisheries management and development.

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[1] Recognition of the multifunctionality of fisheries has been recently attested by the European Commission. “Fishing and aquaculture are professions with a long tradition deeply rooted in the European cultural heritage. Both fisheries and aquaculture contribute to securing a wide variety of food and provide employment in many coastal communities. Therefore, the policy’s social dimension should be given particular attention”, for example through the modernization of the sector and its opening it to a wider social service through the promotion of the fisher’s image as “steward of the sea” (European Commission, 2023d).

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I

LOCAL PARTNERSHIPS FOR THE DEVELOPMENT OF COASTAL REGIONS: A REVIEW OF FISHERIES LOCAL ACTION GROUPS WITH FOCUS ON THE MEDITERRANEAN

2.1. Introduction

Set up in 2007 under Axis 4 of the European Fisheries Fund (EFF), Fisheries Local Action Groups (FLAGs) are local partnerships that bring together the private sector, local authorities and civil society organizations. Since 2014 FLAGs have been responsible for the implementation of community-led local development (CLLD) in European fisheries, an area-based approach initiated by Axis 4 of the EFF and subsequently included into Union Priority 4 (UP4) of the European Maritime and Fisheries Fund (EMFF), whose general objective is to increase employment and territorial cohesion in coastal and inland communities which depend on fishing and aquaculture (European Parliament, 2014). Inspired by the LEADER approach applied to rural areas since 1991, CLLD is described as a bottom-up process that “turns traditional “top down” development policy on its head” (European Commission, 2014) and reflects the change from an exogenous to an endogenous approach of territorial development in the EU (Phillipson and Symes, 2015). The endogenous approach rests on the assumption that well-being of a territory can be best influenced by the human, physical and intangible resources locally available, through the elaboration of development actions that should be based on the extensive involvement of the local community in their design and implementation (Ray, 1999). As such, FLAGs are most advantageously placed to animate local actors by means of multi-sectoral local development strategies which address the needs of coastal communities (Miret-Pastor et al., 2020). Through the involvement of stakeholders from multiple sectors, the 348 FLAGs (as of 2021), distributed across 19 EU Member States, are responsible for the implementation of both sectoral and territorial development- hence tackling those social impacts of the Common Fishery Policy (CFP) that used to be neglected in favor of biological and economic objectives (Piñeiro-Antelo et al., 2019).

Concerning the interaction between sectoral (i.e. for fisheries and aquaculture development) and territorial functions of FLAGs, Miret-Pastor et al. (2020) highlight the fact that majority of objectives that FLAGs can declare are linked with strategies for territorial development, which is in line with the goal of the UP4 itself. Nevertheless, FLAGs can still finance projects related to sectoral development, in particular through the first objective of the CLLD strategies listed in Article 63 of the EMFF (“Adding value, creating jobs, attracting young people and promoting innovation at all stages of the supply chain of fishery and aquaculture products”). In the literature, the debate over the sectoral or territorial nature of EU funds for fisheries dependent areas has been raised long before the establishment of FLAGs (Symes, 2005). Phillipson and Symes (2015) advocate for a “middle way” in the role that FLAGs should play, thus balancing territorial and sectoral projects depending on the socio-economic attributes of the area where they operate, in terms of its dependency on the fishing sector. Specifically, the former approach seeks to enhance resilience through diversification of ‘new’ rural economies, while the latter is aimed at enhancing the sector's sustainability, competitiveness and social renewal.

The necessity to improve the performance of European fishing systems in the three domains of sustainability (social, economic, environmental) has been laid out in various policy initiatives making part of the European Green Deal- namely the EU Biodiversity Strategy for 2030, the Farm to Fork Strategy and the Circular Economy Action Plan. Keeping fishing mortality at or under the MSY (European Commission, 2020b), preventing illegal, unreported and unregulated fishing (European Commission, 2020c), and tackling marine plastic pollution caused by fishing gears (European Commission, 2020a) are some of the actions proposed in these documents. In this regard, FLAGs could play an important role for the sustainable transition of European fisheries. Indeed, it has been estimated that the majority of FLAGs have supported at least one project contributing to the Green Deal objectives, especially those related to the promotion of systems with reduced food miles, education about ecosystems and biodiversity, eco-tourism and sustainable fish stocks management (FARNET, 2020).

In the literature that has investigated the application of CLLD in the EU through FLAGs, some aspects of these organizations have been associated to the key elements of Social-Ecological Systems (SESs). The sustainability of SESs has been extensively studied by means of a holistic framework, developed over several years and continuously updated (Ostrom, 2007, 2009; McGinnis and Ostrom, 2014), which has often been applied in the case of fisheries (Basurto et al. 2013; Leslie et al., 2015; Partelow and Boda, 2015). Linking FLAGs and SESs, Furmankiewicz et al. (2021) claim that the establishment of localized cross-sectoral partnerships for the promotion of bottom-up decision-making processes in the EU should be related to the influential works by Elinor Ostrom on the importance of cooperation at the local level for the management of common-pool resources. Similarly, Linke and Bruckmeier (2015) review the characteristics and benefits of co-management schemes and analyze the potential of FLAGs to develop fisheries co-management in Europe. While investigating on FLAG's potential to promote fishing tourism in Greek small-scale fisheries, also Kyvelou and Ierapetritis (2020) utilize the term SES to convey the embeddedness of traditional fishing activities within the local socioeconomic, cultural and environmental context.

Although FLAGs' interventions are not limited to one specific branch of the fleet, it is argued that the small-scale fishery (SSF) sector tends to be the "natural partner of most FLAGs", since these organizations tend to be located in coastal areas characterized by the strong presence of artisanal fisheries (FARNET, 2017). There exists a solid bond between this type of fisheries and the development of coastal communities (Pita et al., 2020), since the total economic value of artisanal fishing should include "non-commodity outputs" such as the contribution to coastal employment, food security and cultural heritage, among others. These aspects characterize the so-called "multifunctionality" of SSFs (Mulazzani et al., 2019) and have led authors conclude that the economic viability of this type of fisheries cannot be easily summarized through measures of financial profitability (Schuhbauer and Sumaila, 2016). For instance, Mulazzani et al. (2017) have applied the cluster approach to analyze the competitiveness of six coastal communities in the Mediterranean mostly reliant on

SSFs. Their work is based on the analytical framework presented by Malorgio et al. (2017), which allows for the inclusion of a variety of external factors that may affect the performance of SSFs-based territories (e.g. presence of related and supporting industries, demand and inputs conditions, role of governmental institutions and others). Such factors have been derived from the so-called “Diamond Model” first developed by Porter (1998) in his attempt to explain the evolution of successful industrial clusters. Nevertheless, as argued by Malorgio et al. (2017), the multidimensionality of the Porter’s Diamond makes it instrumental in studying the role of SSFs in coastal communities, since it encompasses other approaches that are more specific (i.e. Blue Growth or ecosystem services). For these reasons, not only can CLLD be contextualized within the SES framework, but it could be argued that also the cluster approach to the development of coastal communities provides a useful tool for understanding the contribution of FLAGs to both sectorial and territorial development. Furthermore, the dataset used in the present analysis does not allow to access the information needed to define the typical variables used in those studies using the SES framework and concerning the relationship between resource systems, resource units, governance systems and actors (Partelow, 2018). Under the cluster approach, coastal communities are seen as a particular type of cluster, following the concept of Marshallian districts, where small firms specialize in different production phases and draw labor locally. Michael Porter later popularized the term "industrial cluster" to describe geographical areas with a critical mass of resources and competencies in a particular economic sector. Clusters are bound by external economies, historical roots, and personal relationships, with maritime clusters being analyzed based on both the importance of maritime sectors like shipping, tourism, and fisheries (Fernández-Macho et al., 2015) and the role of innovation, human capital, and social capital in cluster development (Pinto et al., 2015). The success of particular clusters depends on specific local factors, classified by Porter's "Diamond Model."

Since no review has yet been performed on FLAGs, this article attempts to address this gap in order to understand (rather than the effectiveness these organizations had in implementing CLLD strategies) which aspects of FLAGs have been mostly emphasized in the literature. In addition, we want to focus on the differences that characterize the Mediterranean FLAGs from Italy, Spain and France, especially with reference to their organization and strategy. The choice over these three countries is based on their homogeneity with regard to the socio-economic relevance of the Blue Economy, in terms of its contribution to both Gross Value Added and employment at the national level[2]. The study has hence been motivated by the following research questions: 1) Which characteristics of FLAGs have been emphasized in the literature with regard to the six dimensions of the Porter Diamond? 2) Concerning the FLAGs of the Mediterranean basin from Italy, Spain and France, are sectoral and territorial interventions equally prioritized? Results from the two research questions provide for an understanding of the various strategies pursued by FLAGs to foster the socio-economic development of coastal areas taking into account the perspective of both the scientific community and the FLAGs themselves, therefore examining the relation between the two within the Mediterranean region.

[2] Suffice it to say that in the other countries facing the Mediterranean Sea the relative weight of the Blue Economy tends to be much larger. Taking for instance the relevance of employment, its contribution to national jobs reaches 9.8% in Croatia, 10.3% in Cyprus and 15.3% in Greece, well above the EU level (2.3%) (European Commission, 2021).

Considering that the EMFF programming period (2014-2020) has come to an end, the results from this study may provide useful insights for the application of CLLD in the European Maritime, Fisheries and Aquaculture Fund (EMFAF) period 2021-2027. Indeed, the motivation for this analysis can be related the importance attributed to FLAGs in the new EMFAF programming. Particularly, the Italian EMFAF operational program provides a significant example in this context. Despite listing numerous positive aspects and innovative projects in which FLAGs have participated, the program also highlights several critical issues that need to be addressed to promote better utilization of FEAMP funds. Some of the weaknesses highlighted in the operational program are precisely among the aspects considered in our study, as they are integral to a cluster approach to the study of coastal communities (e.g., limited involvement of operators from Blue Economy sectors other than fishing and aquaculture, difficulty in communication between environmental protection operators and productive sectors) (Mipaaf, 2022).

2.2. Methodology and data description

First, a literature review has been performed in order to identify the scientific literature analyzing FLAGs. To do so, the search TITLE-ABS-KEY ("fisher* local action group*") was entered in the Scopus database in February 2022, which resulted in 24 articles already published on the subject. Each of the articles was then analyzed with the aim of extrapolating its methodology, scope of the research, number of FLAGs investigated, geographical area and findings. In order to summarize the main findings related to FLAGs, it has been decided to organize the results section following the analytical framework presented by Malorgio et al. (2017) and applied by Mulazzani et al. (2017) in their comparative analysis of Mediterranean coastal communities. As previously discussed, the variety of interventions pursued by FLAGs and discussed in the literature can fit within the several dimensions of the cluster analysis on costal communities' competitiveness. The six dimensions, derived from Porter's Diamond Model, include *i*) Context for fishermen strategy and rivalry, *ii*) Factors' condition, *iii*) Related and supporting industries and services, *iv*) Demand conditions, *v*) Government, *vi*) History and chance.

The second part of the article, focusing on the Mediterranean FLAGs from Italy, Spain and France, is based on the information available on the FLAGs factsheets and provided by FARNET Support Unit. In particular, for each FLAG the following information were extracted: Country, Surface area, Population density, Total employment in fisheries (Fishing, Aquaculture, Processing), Total public budget allocated to the FLAG for 2014-2020, Presence of fisheries actors in the partnership/general assembly, Presence of public actors in the main decision-making body/board and Strategy. Concerning the information contained in the variable "Strategy", at the beginning of the 2014-2020 EMFF period FLAGs were asked to indicate those subthemes that would be included in their development strategies. FLAGs could choose up to five fields among thirty subthemes, which belong to the objectives of the UP 4 listed in Article 63 of the EMFF: 1) Adding value to fisheries; 2) Diversification; 3) Society and culture; 4) Environment and 5) Governance and management. For each of these macro themes, the variable Strategy indicates how many times they have been declared by the FLAG. The dataset includes those (62) FLAGs that fully reported on each and every single of the above-mentioned variables, coming from Italy (43), Spain (12) and France (7). Concerning the Mediterranean basin, the sample analyzed in the study covers 81% of the Italian FLAGs and the totality of French and Spanish ones. In addition to a qualitative comparison of the selected FLAGs, it is proposed to analyze the FLAG orientation towards sectoral activities in order to understand the relation between the priorities declared by the partnership and its organization. As previously stated, this topic has already been raised in the literature. For instance, the framework by van de Walle et al. (2015) on the role of FLAGs for the resilience of fishing communities can be used to understand whether the organization has been more oriented towards sectoral, territorial development, or a mix of both[3]. In this article, it has been decided to concentrate our analysis on those FLAGs that showed a strong inclination towards sectoral activities. Since all the FLAGs investigated have reported at least one sectoral action, we estimate a logit model where the dependent variable is a dummy taking value 1 if the FLAG declared a minimum of two sectoral activities belonging to the category "Adding value to fisheries" (mean value in the sample) and 0 otherwise. The explanatory variables include the area covered by the FLAG, the ratio of fisheries-related FTEs (full-time equivalents) over the population, the 2014-2020 budget, the percentage of public actors in the FLAG decision-making body, the percentage of fisheries actors in the partnership and the country.

2.3. Results

Table 1 shows the information regarding the 24 articles that resulted from the literature review. As expected, most of the articles focus on those countries where the number of FLAGs is higher, namely Spain (8 articles), Poland (6) and Italy (5). Moreover, it emerges that in the majority of cases qualitative methods of analysis have been preferred, especially through the use of questionnaires and in-depth interviews with FLAGs members (16 articles) and reviews of technical documentation (12). After presenting the main findings according to the six dimensions of the Porter's Diamond, the sectoral/territorial interpretation of FLAGs in the literature is related to the analysis of these partnerships in the Mediterranean Sea, in particular in Italy, Spain and France.

Table 1 – Summary of the information provided by the reviewed articles.

Article	*Methodology*	*Scope*	*FLAGs included in the study*	*Country*	*Findings related to FLAGs*
Cortese et al. (2021)	Questionnaire to consumers, descriptive statistics and Multiple Correspondence Analysis	Understand consumer behavior with reference to local fish consumption	1	Italy	Consumers pay attention to the sustainability of their diet and the environmental impact of fishing techniques. These aspects should be considered by FLAGs with the aim of promoting gastronomic tourism
Czarkowski et al. (2012)	Literature review, legal and strategic documents	Discuss the potential of recreational fishing for tourism development in two Polish provinces	4	Poland	FLAGs should provide the assistance in the management of EU funds for the development of infrastructure associated with recreational fisheries

[3] More specifically, the framework categorizes FLAGs' interventions along an axis which goes from actions focusing on sectoral development- *i*) Sector structure and organization, *ii*) EFF local antenna, *iii*) Small scale fisheries outreach, *iv*) Supply chain integration- to territorial development- *v*) Benefits from blue growth, *vi*) Catalyst for innovation/redevelopment- passing through those interventions where an overlap of both domains takes place- *vii*) Place of sector within a territory, *viii*) Ensuring benefit from local economic development, *ix*) Entry point to local governance.

De Boni et al. (2018)	Application of the multiple criteria decision aiding framework Promethee II, questionnaires to FLAGs' members	Propose a decision tool to assess the sustainability of FLAGs' coastal development plans	6	Italy	Funds distribution should vary among FLAGs, as projects must adapt to the environmental and socio-economic features of the area. It is better to fund projects in different sustainability fields
Distaso et al. (2020)	Interviews with FLAGs' directors, Analytic Hierarchy Process Methodology	Evaluate the role of local FLAGs at improving the quality of life in one Italian region	6	Italy	FLAGs should organize activities to increase social capital and provide diversification opportunities
Freeman and Svels (2022)	Quantitative assessment through surveys and semi-structured interviews with local stakeholders and FLAG members	Study the impact of FLAGs on women's empowerment	113	EU-wide, focus on Estonia, Croatia, Spain	FLAGs are active in promoting the empowerment of women in fishing communities (especially in the domain of diversification projects) but in many cases they are still dominated by male perspectives, thus underrepresenting women's contribution to SSFs survival
Furmankiewicz et al. (2021)	Review of technical documentation, content analysis and text mining	Analyze whether CLLD strategies in Poland address issues related to climate change mitigation and adaptation	36	Poland	FLAGs' strategies do not sufficiently include efforts for mitigation and adaptation. Communities are only aware of local impacts on fishing activities and disregard the involvement in European initiatives
García and Piñeiro-Antelo (2021)	Review of technical documentation	Analyze cooperation projects in Galicia, in terms of their scope and weight within local development strategies	7	Spain	There is an increase in cooperation projects by FLAGs, but their number is still too limited. Plus, efforts should be made to extend their geographical coverage
Kurowska et al. (2014)	Hellwig's taxonomic method to combine socioeconomic indexes into four levels of local development	Assess the impact of FLAGs on the socioeconomic development of Polish coastal regions	9	Poland	The socioeconomic development level in FLAGs areas increased between 2004 and 2012
Kyvelou and Ierapetritis (2020)	Review of technical documentation, survey and interviews to FLAGs' members and other stakeholders	Evaluate the benefits and challenges of establishing marine spatial plans promoting fishing tourism	17	Greece	FLAGs should collaborate with marine spatial planning authorities and other marine sectors for the creation of multi-use schemes, especially fishing tourism due to its environmental and socioeconomic value
Linke and Bruckmeier (2015)	Literature review on co-management, policy documents analysis, talks and interviews with FLAGs' members and other stakeholders	Identify those conditions that allow the implementation of co-management schemes in European fisheries	Not specified	Denmark, Finland, Sweden	FLAGs have the potential to empower local fishing communities, provided that they integrate knowledge from all relevant stakeholders. Involving FLAGs in higher-level decision-making processes is key
Miret-Pastor et al. (2018)	Review of technical documentation, questionnaire sent to FLAGs' managers, descriptive statistics	Analyze fisheries diversification projects in Spain and evaluate their effectiveness	24	Spain	Most of FLAGs' leaders acknowledge the importance of diversification projects for the development of coastal areas. However, actions should not be limited to tourism and include social and environmental issues
Miret-Pastor et al. (2020a)	Review of technical documentation	Study the use of EFF funds in Spain to provide for diversification opportunities by connecting the tourism sector, recreational and professional fishing	31	Spain	Fishing tourism projects are still scarce. The following points should be addressed by FLAGs: fishermen involvement, use and improvement of existing infrastructures, communication at the community level, participation in governance processes and training to share knowledge with different actors
Miret-Pastor et al. (2020b)	Review of technical documentation	Study the distribution of project funds on UP4 objectives among FLAGs from eight European countries	131	Denmark, Estonia, Finland, Ireland, Latvia, Poland, Spain, Sweden	Most of the expenditures addressed three objectives (adding value, diversification, socio-cultural promotion). But new indicators to measure the impact of FLAGs' projects should be developed

Mulazzani et al. (2017)	Consultation of an interdisciplinary research team and local stakeholders	Build a model based on the ecosystem service framework and the Bayesian network approach to simulate the socio-ecological outcomes under different scenarios	1	Italy	The application of the proposed model by FLAGs represents an opportunity to empower the local community due to its participatory approach
Padín et al. (2016)	Tourist surveys and interviews with FLAGs' members and local skippers	Assess two fishing tourism projects in Galicia	2	Spain	FLAGs' members highlight the positive effects of fishing tourism on fishermen's environmental awareness, social image and diversification opportunities
Pawlewicz et al. (2014)	Surveys, audit visits and interviews with FLAGs' members and other institutional representatives	Analyze the activities performed by Polish FLAGs concerning environmental protection	41	Poland	Despite FLAGs' potential, the number of projects to protect the natural heritage in Poland is low. The influence of the public sector and the lack of involvement of private parties represent an obstacle
Phillipson and Symes (2015)	Interviews with FLAG's members and other stakeholders from the local community and fishing sector, review of technical documentation	Examine how FLAGs projects can balance sectoral and territorial development	1	United Kingdom	The targets of EFF Axis 4 funds should be redefined. A typology of fisheries dependency is proposed to help FLAGs plan their investments conditional on the place of the fishing sector within the local economy
Piñeiro-Antelo & Lois-González (2019)	Review of technical documentation, interviews with members of the local fishing sector	Analyze the contribution of CFP funds to the generation of social innovation	1	Spain	The FLAG generated social innovation locally, but it was limited by community resistance, unequal representation of interests and pressures from the administration
Piñeiro-Antelo et al. (2019)	Review of technical documentation, interviews with FLAGs' members and project managers	Assess the activity of two FLAGs, in terms of their ability to be socially inclusive, sectorally balanced and autonomous in the distribution of funds	2	Spain, Portugal	FLAGs have promoted positive social innovations, but they were limited by the scarcity of funds, the influence of local administrations and the unequal weight given to their members
Piñeiro-Antelo et al. (2020)	Review of technical documentation, interviews with FLAGs' members and participation to a FLAG workshop	Study the role of FLAGs in territorial governance processes in the context of the Evolutionary Governance Theory framework	13	Ireland, Spain	FLAGs have been effective in empowering local actors and create synergies among different economic sectors, but their influence depended on the existing governance system, especially in terms of pressures from local authorities
Romeo and Marcianò (2019)	Interviews with vessel owners and FLAG's members, budgetary analysis, multi-criteria analysis in a fuzzy environment	Assess the economic performance of the main fishing gear types active in the FLAG area	1	Italy	FLAGs should perform microeconomic analysis of the local fleet to help plan local development strategies
Szamrowski et al. (2014)	Surveys, audit visits and interviews with FLAGs' members and other institutional representatives	Analyze the activities performed by Polish FLAGs regarding environmental protection	4	Poland	The number of projects aimed at protecting the natural heritage in Warmia and Mazury is low. Most of the funds are allocated to the objective of increasing the competitiveness of fisheries areas
Thuessen and Nielsen (2014)	Focus groups with LAGs and FLAGs' board members and coordinators	Study the contribution of the EU LEADER approach in a multi-level governance setting at the LAG and FLAG level	3	Denmark	LAGs and FLAGs represent an opportunity to develop local development strategies in bottom-up decision-making processes
van de Walle et al. (2015)	Interviews with FLAG's members and review of the FLAG technical documentation	Describe the projects that the Pays d'Auray FLAG has pursued to respond to pressures on the local fishing sector	1	France	FLAGs represent an important forum to mitigate the fragmentation among different fisheries actors and to advocate for the needs of the local fishing sector

2.3.1. Context for fishermen strategy and rivalry

This dimension includes the performance of the local fishing fleet and the relationships both among fishermen and within the value chain. The work by Romeo and Marcianò (2019) constitutes the only example of a study on FLAGs with the aim of assessing the performance of the fleet. The article provides for a methodology to aggregate scores of financial indicators derived from budgetary analysis of the vessels into a measurement of the economic performance of the main gear types adopted in the area, thus helping the local FLAG plan a development strategy that addresses the issues and potentials of the different fishing systems. With regard to the nature of the relationships within the fishing industry, it has been emphasized that FLAGs represent a forum to overcome the fragmentation of the fishing sector (van de Walle et al., 2015) and promote regional cooperation (García and Piñeiro-Antelo, 2021).

2.3.2. Related and supporting industries and services

A recurring topic raised in the literature is the importance of improving the connection between the fishing and tourism sectors. In their analysis of fishing tourism projects in Galicia, Padín et al. (2016) claim- based on interviews with local FLAGs' managers- that these initiatives are especially beneficial in enhancing the social image of fishermen, changing it "from a predatory role to a resource manager", and spreading environmental awareness among both tourists and the fishing sector. Kyvelou and Ierapetritis (2020) investigate the benefits and problems related to the co-existence of artisanal fisheries and tourism and present fishing tourism as an effective diversification strategy for Greek small-scale fisheries. The authors stress the role that FLAGs could play in the establishment of marine spatial plans through a multi-use approach that guarantees the coexistence of different economic sectors. Miret-Pastor et al. (2020) illustrate practical examples of activities that may connect recreational and professional fishing and claim that the number of projects that unite these two sectors in Spain is still too limited. While evaluating the distribution of Spanish diversification funds in the period 2007-2014, Miret-Pastor et al. (2018) report FLAGs' opinion that restoration and gastronomic events are the two diversification activities that generated the highest profits for the fishing industry. Lastly, Czarkowski et al. (2021) encourage Polish FLAGs to provide assistance in managing EU funds for the promotion of recreational fishing in lakeland regions, in terms of infrastructures designed for anglers.

2.3.3. Demand conditions

The elaboration of adequate strategies for the development of a successful marine cluster should also take into account the level and characteristics of local demand, investigating its sophistication and specialization degree. Overall, we highlight a lack of studies relating the role of FLAGs to the analysis of exclusively local consumer demand. As previously discussed, sectorial aspects like marketing strategies and consumer analysis have been only partially investigated in the literature concerning FLAGs, stressing once again the territorial development function of these organizations. The only exception is represented by Cortese et al. (2020), whose objective is to provide for an analysis of consumer behavior in the area of one FLAG in

Southern Italy. The study, meant to help planning local programmes of gastronomic tourism, highlights the association that tourists make between small-scale fishing activities and the sustainability of the production process. A tourist survey is present also in Padín et al. (2016), although in this case the objects of the analysis are two diversification projects of fishing tourism. Regarding the strategies to improve the attractiveness of the cluster, van de Walle et al. (2015) claim that one of the key factors in the case of the Pays d'Auray FLAG was the presence of "active fishing harbours and working shellfish farms", hence warning- following Martindale (2014)- against those forms of tourism that tend to reduce the fishing industry to some sort of cultural heritage rather than a dynamic economic activity.

2.3.4. Factors conditions

This dimension is related to the availability and quality of those inputs that contribute to the development of a successful coastal cluster, like natural and physical capital and labor. The literature that has investigated on the link between FLAGs and the management of such factors includes a limited number of articles and is mainly focused on investments for the enhancement of environmental assets and climate change mitigation, which belong to the fourth objective of Article 63 of the EMFF. In their analysis covering eight EU Member States, Miret-Pastor et al. (2020) show that FLAGs have assigned to environmental projects the lowest priority among the five objectives of the UP4, with Swedish FLAGs constituting one exception due to their large geographical coverage, which allows them to have access to the larger funds needed to address complex issues like environmental management. Investments in the area of environmental protection are explored also in Szamrowski et al. (2014) and Pawlewicz et al. (2014), where it is argued that the level of funds dedicated to these activities by Polish FLAGs is too low. Furmankiewicz et al. (2021) have reviewed Polish FLAGs' development strategies to study the relevance given to climate change mitigation and adaptation activities. After showing that these issues have been only marginally discussed, the authors advocate for interventions favoring the development of environmental awareness on the most concrete effects of climate change among local stakeholders and the tangible benefits deriving from investments in renewable energy.

2.3.5. Government

The capacity of institutions to influence the development of maritime clusters should be broadly conceived, as it embraces a variety of activities such as financial support, environmental legislation and community empowerment. In this regard, the literature tends to stress the positive contribution that FLAGs have made to the implementation of CLLD across Europe. For instance, in their analysis of Irish and Galician FLAGs, Piñeiro-Antelo et al. (2020) claim that these organizations have fostered the evolution of local territorial governance, by giving greater prominence to local actors and generating synergies among different sectors. However, the authors also stressed that FLAGs' effectiveness and acceptance is heavily influenced by the already existing territorial governance framework. Likewise, the weight of local elites and public administrations in the choices over funds allocation has been reported as a limiting factor in Piñeiro-Antelo et al. (2019) and Szamrowski et al. (2014). In this regard, van de Walle et al. (2015) argue that it is the overrepresentation of fishermen within the board composition that has successfully allowed the Pays d'Auray

FLAG to mobilize the concerns of the local fishing industry, at the expenses of other sectors whose interests are already widely represented. Similarly, Thuessen and Nielsen (2014) hold that that the establishment of (F)LAGs has developed multilevel governance settings in Denmark “in the form of leverage, democratization and bottom-up decision making”.

2.3.6. History and chance

Even if it is believed that historical events external to FLAGs (e.g. indirect drivers of change like economic crises and political instability) should be considered during the elaboration of local development strategies (Mulazzani et al., 2017), no general conclusions can be drawn from the reviewed articles over the influence of history and chance on FLAGs. Nevertheless, in several studies the discussion on FLAGs is contextualized within external factors of change like anthropogenic pressures (van de Walle et al., 2015), declining fishing profitability (Kyvelou and Ierapetritis, 2020) or the inclusion of Axis 4 in the CFP (Piñeiro-Antelo et al., 2019).

2.3.7. FLAGs in the Mediterranean basin - Italy, Spain and France

With regard to the regional analysis on FLAGs, Table 2 provides some information concerning the structure and organization of these partnerships in Italy, Spain and France. When looking at the geographical extension of FLAGs, it emerges that the seven French groups in the Mediterranean basin tend to be characterized by a relatively wider coverage in territories with scarce population densities. Moreover, in these areas the frequency of fisheries-related jobs seems lower if compared to Italy and especially Spain. Indeed, Mediterranean Spanish FLAGs are the ones that have received the greatest allocation of funds, thus reflecting the socio-economic relevance of the Blue economy in the country (4.9% of national jobs in terms of employment and 3.0% of national GVA) (European Commission, 2021). The presence of public actors in the decision-making board- whose excessive control on the organization’s activities has already been discussed in the literature review- is another characteristic that tends to vary among the three countries, reaching its peak in French FLAGs (43%). On the contrary, substantial homogeneity can be found when looking at the priority that FLAGs have assigned to the UP4 objectives. With respect to their strategy, the relatively low attention to environmental issues- as already highlighted in the literature review- tends to be a common characteristic of FLAGs in the region. On the contrary, the theme “Adding value to fisheries” has been declared at least once by all the 62 FLAGs investigated and also the theme “Diversification” has been frequently included in the strategy (77% of FLAGs). In absolute terms, actions belonging to the theme “Adding value to fisheries” have been declared the highest number of times (119), followed by “Diversification” (61), “Society and culture” (52), “Governance and management” (51) and “Environment” (29). Indeed, it emerges that FLAGs have prioritized sectoral interventions over territorial ones. Nevertheless, it is important to remark that there is a relevant number of FLAGs that have declared a number of actions under “Diversification” at least equal to or greater than those falling under “Adding value to fisheries” (32.6% of FLAGs in Italy, 75% in Spain and 42.9% in France).

Table 2 – Descriptive statistics of the variables contained in the FLAGs' factsheets of the selected countries. Only coastal FLAGs in the Mediterranean are included.

	Italy	*Spain*	*France*
N. FLAGs analyzed (*% coverage*)	43 (*81%*)	12 (*100%*)	7 (*100%*)
Average population density (*inhabitants/ km²*)	495	468	288
Average surface area (*km²*)	619	450	1055
Average frequency of fisheries FTEs in the population	0.60%	0.91%	0.36%
Average public budget allocated to the FLAG for 2014-2020	1,683,439 €	2,485,936 €	1,451,059 €
Average presence of public actors in decision-making body	33%	28%	43%
Average presence of fisheries actors in partnership	32%	32%	37%
FLAGs with at least one environmental subtheme declared	17/43	6/12	4/7
FLAGs with at least one diversification subtheme declared	32/43	11/12	5/7
FLAGs with at least two sectoral subthemes declared	30/43	3/12	4/7

To complete our investigation of Mediterranean FLAGs in Italy, Spain and France, it is suggested to analyze the relationship between the main characteristics of the organization and the preference towards sectoral interventions rather than territorial ones. Considering the small sample size (62 FLAGs), we apply the Firth's (1993) penalized maximum likelihood estimator, which allows for a reduction in both the bias and the variance that affect maximum likelihood estimates of logit models for small samples (Rainey and McCaskey, 2021)[4,5].

Table 3 – Results of logistic regression analysis to explain the sectoral orientation of FLAGs.

Variable	*Coefficient*	*SE*
Constant	0.442	1.444
Surface area	0.000	0.000
FisheriesFTEs/Population	3.435	1.596 *
Public budget	0.000	0.000
% of public actors	-0.003	0.028
% of fisheries actors	-0.035	0.020
France	1.094	1.085
Spain	-0.164	1.016

[4] In addition to the low number of observations, this method is preferred over a Poisson regression due to the fact that- as directly reported by FARNET members- several FLAGs did not respect the maximum number of points (5) they could declare, thus not leading to a distribution with univocal right-truncation point.

[5] In order to obtain parameters estimates in a logit model explaining a binary outcome, a log-likelihood function needs to be maximized. The solution proposed by Firth (1993) consists in the penalization of the usual likelihood function $L(\beta/y)$ by a factor equal to the square root of the information matrix $|I(\beta)|^{1/2}$.

It results that the only independent variable which is statistically significant at the 5% significance level (p-value = .031) is the ratio of fisheries-related FTEs over the population of the FLAG territory. As expected, an increase in the frequency of local workers employed in Fishing/Aquaculture/Processing sectors is estimated to lead to a higher chance of a strong presence of sectoral priorities in the FLAG strategy. None of the other variables seem able to predict the sectoral/territorial dimension of FLAGs in the selected countries of the Mediterranean Sea, but the low number of observations involved suggests that these results should be cautiously interpreted and deserve further investigation.

2.4. Discussion

Results from the literature review have stressed the role that FLAGs could play in the development of successful maritime clusters according to the Porter's Diamond Model. In particular, it seems that scientific contributions on FLAGs have highlighted the importance of these partnerships in the establishment of linkages and collaborations between the fishing sector and other industries and services of the Blue Economy in the area where the FLAG operates. According to Article 3 of the EMFF Regulation, such a territory should be "an area with a sea, river or lake shore, including ponds or a river basin, with a significant level of employment in fisheries or aquaculture, that is functionally coherent in geographical, economic and social terms and is designated as such by a Member State". Considering that the additional selection criteria that Member States have adopted in their operational programmes tend to require some local characteristics of economic disadvantage with respect to the rest of the regional territory, FLAGs have the potential to provide for diversification opportunities in fisheries-dependent communities with declining socio-economic conditions[6].

Connecting the previous results from the two research questions, it can be said that there is an evident contrast between the role of FLAGs that has been most commonly emphasized in scientific articles and the actions that these organizations have prioritized during the 2014-2020 programming period. If on the one hand territorial actions are the ones that received most of the attention in the literature (as demonstrated by the interest on themes like environmental protection, community empowerment and fishing tourism), on the other it is clear that FLAGs have prioritized projects of sectorial scope. Nevertheless, as already stressed by Miret-Pastor et al. (2020), this type of analysis is limited by the fact that the interpretation of the definitions of the five objectives of Article 63 of the EMFF tends to vary among countries, hence FLAGs from different Member States may declare diverse UP 4 objectives for projects that are actually similar in their scope.

It is argued that further attempts to analyze FLAGs' activities and organization should take into account the relevance of the Blue Economy in the territories under investigation. In this regard, the last EU Blue

[6] As an example, the Italian operational programme for the programming period 2014-2020 (Mipaaf, 2015) requires fisheries and aquaculture areas to present at least one of the following socio-economic attributes to be eligible for CLLD funding: *i*) a reduction in the fishing fleet of more than 10% in relation to the value in 2007, in terms of either gross tonnage or engine power and/or a reduction in the value of production of more than 10% in relation to the value of 2007, *ii*) population density equal to or lower than the regional average, *iii*) unemployment rate equal to or higher than the regional average.

Economy Report (European Commission, 2021) includes detailed socio-economic data describing the evolution of its established sectors (Marine living resources, Marine non-living resources, Marine renewable energy, Port activities, Shipbuilding and repair, Maritime transport and Coastal tourism). Explaining the development strategies that FLAGs from different countries have established should probably take into consideration also the long-term dynamics within the sectors of the Blue Economy. For instance, combining data on local opportunities for diversification (especially in the tourism sector) with the information on the FLAGs' composition and development strategies may help explain the partnerships' prioritization of either territorial or sectorial interests. This suggests the validity of the cluster approach to the study of maritime communities due to its inclusion of several dimensions that may affect the competitiveness of the local economy where the FLAG intervenes.

2.5. Conclusions

The present paper provides for a literature review of those scientific articles that have analyzed the role of FLAGs for the sustainable development of coastal communities. It has been attempted to organize the main findings from the literature according to the six dimensions of the Porter's Diamond, thus interpreting the FLAG as a factor that can contribute to the emergence of successful maritime clusters in the European Union. Although in the literature it is possible to find examples covering all the dimensions of the Diamond, issues related to the ability of FLAGs to establish links with other industries and services of the costal economy (in particular the tourism sector) received special attention. Overall, most of the articles tend to focus on the territorial dimension of FLAGs, hence stressing the four non-sectoral objectives that FLAGs can receive support for according to Article 63 of the EMFF on the implementation of CLLD strategies. However, when looking at the priorities declared at the beginning of the 2014-2020 programming period by FLAGs belonging to the Mediterranean basin from Italy, Spain and France, it results that sectoral interventions connected to the theme "Adding value to fisheries" were given precedence. In order to link the choice over sectorial or territorial functions with the characteristics of the FLAGs from the three selected countries, information provided by the FLAGs' factsheets from FARNET were used to explain the preference towards sectoral interventions. In this regard, the relevance of employment in fisheries-related sectors in the territory where the FLAG operates seems to be the only significant variable positively affecting the prioritization of sectoral activities. Further research may address this point by extending this type of analysis to other countries of the Mediterranean or the European Union. Considering that Member States are currently facing the challenge of translating the new EMFAF regulation into their national operational programmes, predicting the likely allocation of funds for which FLAGs will receive support (now under Priority 3, "Enabling a sustainable blue economy in coastal, island and inland areas, and fostering the development of fishing and aquaculture communities") may translate into a more effective application of CLLD in European maritime regions. To conclude, it can be claimed that the bottom-up approach to territorial governance through FLAGs represents an important contribution to the endogenous development of coastal regions in the European Union, but the effectiveness of these partnerships is highly dependent on the context where the FLAG operates. The use of the Porter's Diamond to guide the definition of local development strategies may thus constitute a valuable tool at FLAGs' disposal.

Nevertheless, improving the coordination between the private and public sectors and strengthening the role of local partnerships in terms of operational planning represent two significant points to be addressed in order to fully capitalize on the socio-economic and environmental potential of coastal communities. The renewed support aimed the sustainable development of maritime regions expressed by the EMFAF and the other European Funds can promote this transition.

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III

RECREATION IN COASTAL ENVIRONMENTS: ESTIMATING THE NON-MARKET VALUE OF FISHING HARBORS

3.1. Introduction

The fishing sector may serve the realization of multiple objectives, as appropriately described by the concept of multifunctionality, which is commonly used to indicate the joint production of both material and immaterial goods from farming activities (OECD, 2001; Renting et al., 2009). While the term was originally applied to agriculture, it has been recognized that fisheries can also be interpreted as providers of services that go beyond food production (Ropars-Collet et al., 2017). Mulazzani et al. (2019) have identified six categories of non-commodity outputs from fisheries: *i*) healthy ecosystems and biodiversity, *ii*) other environmental public goods/bads, *iii*) cultural heritage and coastal viability, *iv*) coastal employment, *v*) food security and *vi*) strategic benefits. Most of these non-commodity outputs show the characteristics of externalities or public goods, thus justifying the adoption of fisheries management that secures the provision of these services at the socially optimal level (Shortle and Uetake, 2015).

Strictly linked to multifunctionality, the concept of total economic value allows for a comprehensive assessment of environmental goods through the incorporation of both their use and non-use values, which can be estimated through non-market valuation techniques (Pearce et al., 2006). The literature focusing on the determination of the total economic value of ecosystems and biodiversity is extremely rich: in the case of marine resources typical examples include coral reefs (Cruz-Trinidad et al., 2011; Madani et al., 2012), mangroves (Gunawardena and Rowan, 2005; Rizal et al., 2018), vertebrate animals (Clua et al., 2011; Teh et al., 2018) or coastal areas in general (Aanesen et al., 2010; Fu et al., 2018) (see Remoundou et al. (2009) for an economic classification of coastal and marine values). In the case of fisheries, Barnes-Mauthe et al. (2013) used the concept of total economic value to describe the multiple contributions made by the small-scale fishing sector to the livelihood of coastal communities in Madagascar, but their analysis is limited to observable and quantifiable indicators of landings and profitability.

Recognition of the different functions fulfilled by the fishing sector has also influenced the allocation of structural funds supporting the EU Common Fisheries Policy. One significant example of such a broad interpretation of the role of fisheries has been the establishment of Fisheries Local Action Groups (FLAGs), which are area-based partnerships bringing together the private sector, local authorities and civil society organizations, whose aim is to increase employment and territorial cohesion in coastal and inland communities which depend on fishing and aquaculture (European Parliament, 2014). The connection between small-scale fisheries (SSFs) and the attractiveness of coastal environments is explicitly stated in the recent Regulation establishing the European Maritime, Fisheries and Aquaculture Fund (EMFAF), which claims that SSFs “are vital to the livelihood and cultural heritage of many coastal communities in the Union”, thus justifying the adoption of ad hoc measures supporting the sector (European Parliament, 2021). In addition, various studies have argued that the total value of SSFs should incorporate their wider contribution to non-monetary measures of social wellbeing (Johnson, 2018), for instance through the maintenance of community cohesion and cultural identity (Lowitt et al., 2020; Tzanatos et al., 2020). Taking into account the major weight of the European Union (EU) with respect to the global allocation of subsidies to fisheries (Sumaila et al., 2019), quantification of the non-commodity outputs produced by the fishing sector is needed to justify its financial support by the EU.

One notable non-commodity output is recreation. It has long been recognized that fisheries generate many cultural ecosystem services for the benefit of the general population, including recreational opportunities (Ghermandi et al., 2010). In the literature it is common to find claims that fishing activities and harbors represent recreational amenities for tourists and visitors. More specifically, the presence of fishing vessels and related activities, such as direct selling of freshly caught food, equipment unloading by the docks and festivals celebrating fishing culture, constitutes a valuable asset promoting tourism (Arthur and Mensah, 2006; Gilden, 1999; Jung et al., 2014; Khakzad and Griffith, 2016; Lacher et al., 2013). Indeed, similar strategies can be found in various examples of touristic initiatives capitalizing on the tangible and intangible cultural heritage of fisheries (FARNET, 2014; Konior, 2018; Rogelja, 2004; Yüksel and Akgül, 2007). Fisheries are also deemed to maintain social cohesion and cultural identity in many coastal communities, both in developed and developing countries (O'Garra, 2009; Oleson et al., 2015), thus suggesting that the enjoyment of fishing operations in the local harbor constitutes an important recreational experience for the local population (Lange and Ounanian, 2020). It is important to stress that the attraction provided by fishing harbors has been frequently associated with SSFs rather than industrial fisheries (Malorgio et al., 2017; McCoy, 2015; Mulazzani et al., 2019; Stobberup et al., 2017).

Non-market valuation methods can be applied to estimate these recreational values. We focus on the recreational value of the fishing fleet to the general population rather than the value of recreational fishing, which has already been the object of a large number of studies (Ezzy et al., 2012; Pokki et al., 2018; Terashima et al., 2020; Toivonen et al., 2004). Attributing a recreational function to fishing fleets is based on the premise that the total economic value of fisheries should include both the direct benefits associated with the provision of fish products as well as some other forms of cultural services. This reflects the idea that cultural ecosystem services can be seen both as a product of the ecosystem (the fish stock) and the human activities interacting with it (the fishing fleet). Indeed, cultural ecosystem services are best described as a product of a relational process between people and the ecosystem (Fish et al., 2016).

The number of empirical studies assessing these values is limited. While empirical analysis has provided evidence in favor of the existence of a non-use value of fisheries (Durán et al., 2015; Ropars-Collet et al., 2017), other studies have produced mixed results with regard to their use component (Andersson et al., 2021; Pascoe et al., 2023; Waldo et al., 2023). Moreover, despite the intuition that SSFs may incorporate a higher non-market value than their large-scale (LSFs) counterpart (e.g. through the preservation of cultural heritage and the attraction of tourists (Bull, 2007; Mulazzani et al., 2019)), the only article that has accounted for this distinction has not found conclusive proof supporting this claim (Andersson et al., 2021).

The present paper addresses this line of research by deepening our understanding of the use value of fisheries by using the travel cost method (TCM). In particular, we estimate the recreational services generated by fishing fleets. The analysis takes into consideration various characteristics of the fishing fleets registered in the harbors of ten European countries to test whether fisheries-related variables motivate recreational behavior in marine environments. In particular, we are especially interested in *i*) understanding whether the fishing capacity[7] of the fleet registered at the harbor affects recreational behavior, or whether fishing presence suffices regardless of capacity; and *ii*) differentiating between SSF and LSF vessels. The latter point is motivated by the lack of empirical evidence supporting the belief of the higher level of attractiveness of SSF vessels versus LSF ones. Even if we do acknowledge that economic valuation may not be able to capture the entire value that coastal communities place on fisheries (Acott and Urquhart, 2014; Khakzad and Griffith, 2016), our concern regarding the relationship between SSFs and recreation addresses the need for empirical valuation of cultural heritage (Cellini, 2011). In order to answer the two research questions, the analysis controls for some specific fisheries-related variables describing the fishing capacity near the visited location, namely the presence of a fishing harbor and the number, tonnage and power of fishing vessels, discriminating between small-scale or large-scale (industrial) fisheries.

To investigate the role of fishing capacity on visitation, we employ a large European dataset used by Börger et al. (2021) and expand their analysis to explain the relationship between fisheries and recreation. The use of a large dataset characterized by broad multicountry coverage is unique in the Travel Cost method literature, and allows us to test for the generalization of the local and regional level results from previous studies (Le Gallic et al., 2015; Pascoe et al., 2023; Ropars-Collet et al., 2017; Waldo et al., 2023). Considering the reduction in fishing capacity that has taken place in the EU since the early 2000s (Bell et al., 2017; Raicevich et al., 2020; Sánchez Lizaso et al., 2020), measuring the demand for recreational trips as a function of fishing fleets can guide policymakers in assessing whether there is a risk of under provision of small-scale fishing capacity and the recreational services they provide due to their nature as a public good.

3.2. Methodology

Non-market values can be estimated with two distinct methods: Revealed and Stated Preference methods. The former are based on the observation or reporting of individual behavior in relation to environmental goods and attributes to reveal people’s implicit preferences towards changes in their quality or quantity, while the latter use hypothetical questions designed to elicit the value that the respondents place on the environment in terms of their willingness to tradeoff money for environmental goods (Champ et al., 2003; Freeman III et al., 2014). Stated preference methods are tailored to estimate value changes when non-use

[7] Fishing capacity indicates the potential output of a fleet in terms of landings when the factors of production are optimally employed. In order to support fisheries management plans, this is usually translated into an equivalent physical measure describing the structure of the fleet in terms of number of vessels, engine power or gross tonnage (Pascoe et al., 2001).

values are substantial. Revealed preference methods are adequate when the goal is to infer on changes in use values alone.

3.2.1. Non-market valuation of fisheries

Two studies have applied stated preference methods to estimate use and non-use values related to fisheries. The earliest example of a stated preference study is given by Durán et al. (2015), who estimated the values associated with the conservation of maritime and fishing cultural heritage in Galicia using discrete choice experiments. The results indicated a positive willingness to pay for the protection of both intangible (fishermen's knowledge, folklore) and tangible (fishing architecture, traditional boats) heritage. A stated preference approach to the non-market valuation of fisheries can also be found in Ropars-Collet et al. (2017), whose focus was the influence of amenities linked to the existence of commercial fishing activities in determining the recreational demand at seaside locations in France, Belgium and the United Kingdom. Evidence from the discrete choice experiments showed that both the presence of fishing vessels and the direct sale of seafood positively contributed to the utility of the respondents, especially with regard to the former attribute.

Other studies have applied revealed preference methods to explore the positive externalities that fisheries can bring to coastal communities by increasing their level of attractiveness. Andersson et al. (2021) investigated the relationship between fishing variables (i.e., landings and number of vessels, differentiated between large and small-scale) and tourism demand using a panel dataset covering 58 coastal municipalities in Sweden over the period 1998–2015. Although they found a statistically significant positive relationship between fishing activity and overnight stays when applying ordinary least squares, the results did not hold with fixed effects estimation, which controlled for the unobserved heterogeneity among the municipalities under consideration. On the other hand, in their contingent behavior travel cost analysis of touristic visits to the coastal town of *Mooloolaba* in Australia, Pascoe et al. (2023) demonstrated that a reduction in the number of visitors would take place if there were no fishing industry or the opportunity to eat local seafood. Moreover, the qualitative information gathered during the survey suggested that the view of the local fishing fleet would increase the interest in eating locally caught fish, which implies the existence of a positive externality from the fishery to other sectors of *Mooloolaba* economy. Similar conclusions were also reached by Le Gallic et al. (2015), who demonstrated that 34% of the visits to the French municipality of *Le Guilvinec* were specifically motivated by the presence of a fishery, as indicated by the fact that the activities linked to the fishing character of the town (walking in the harbor, looking at vessels, buying/eating seafood) were among the most frequently reported by tourists. Lastly, the study by Waldo et al. (2023) combines in-depth interviews with local tourism representatives and a questionnaire survey of 647 tourists who visited the *Träslövsläge* harbor to investigate the impact that the decline of Swedish SSFs may have on the marine tourism industry. Through the use of the TCM and stated preferences, the paper shows that the number of one-day visits would decrease without fishing-related attributes. In particular, the findings reveal that tourists value the presence of fishing vessels at approximately 9 percent of the total value of their visit. In contrast, fishing architecture and a harbor with active commercial fisheries are rated lower in importance. Interviews suggest that the fishing industry plays a crucial role in defining the village's character, but the overall touristic experience also relies on additional activities such as restaurants and water sports, to the extent that the significance of fishing-related attributes varies considerably among tourists.

3.2.2. The travel cost method

In this paper we apply the TCM to estimate the recreational value associated with fishing presence and capacity. The use of a revealed preference method like the TCM is appropriate if the researcher aims at estimating recreational use values, rather than other use or non-use values (Perman et al., 2003). First suggested by Hotelling in his famous letter to the US Park Service in 1947 (Hotelling, 1947) and later developed by Clawson (1959) and Clawson and Knetsch (1966), the TCM has been widely used to value the recreational use values of a variety of environments, such as wetlands (Gürlük and Rehber, 2008), mountain forests (Hesseln et al., 2003), lakes (Fleming and Cook, 2008), coastal beaches (Bin et al., 2005), marine protected areas (Chae et al., 2012) but also historical and cultural sites (Bedate et al., 2004; Tourkolias et al., 2015). The TCM considers the expenditures that the user incurs to enjoy the outdoors as their implicit price, for example including fuel costs and the opportunity costs of time (Phaneuf and Smith, 2005). If recreation trips are ordinary goods, then the frequency of visits to a recreation site should diminish if the travel cost increases (Bockstael and McConnell, 2007).

Outdoor recreation involves the participation in any leisure activity in the natural environment, such as ocean swimming or boating, and is a benefit derived from cultural ecosystem services (Haines-Young and Potschin, 2017). In certain scenarios, outdoor recreational areas like alpine skiing resorts are managed through market-based systems. However, recreational use of the environment is more commonly characterized as a public good, with both free entry and no consumption restrictions (Phaneuf and Requate, 2016). Having the characteristics of non-excludability and non-rivalry in consumption, recreational experiences are not traded in markets and therefore, despite generating substantial benefits to visitors of these sites (White et al., 2020), they share with other environmental goods and services the risk of undersupply relative to the social optimum (Champ et al., 2003). Using the choices revealed in markets or responses to questionnaires as proxies for visitors' preferences, non-market valuation methods are able to capture the changes in welfare associated with modifications in the provision of recreational opportunities, thus providing crucial information for resource management decisions (Bishop and Boyle, 2019; Freeman III et al., 2014).

The TCM typically uses survey data from samples of recreational visitors. To operationalize the TCM, the researcher can opt for the zonal TCM, the individual TCM or the random utility TCM (Phaneuf and Smith, 2005). In this work, we apply the individual TCM (which analyzes the number of visits chosen) rather than the random utility TCM (which analyzes which sites were chosen), given the lack of detailed individual level information and on potential substitute sites. We apply the so-called "typical site approach" of TCM studies, meaning that we do not consider only one specific location but we rather treat similar sites (coastal environments) taken together as one "typical" site (various examples of this technique can be found in Ezebilo (2016)).

We then estimate a trip demand equation to extract consumer surplus per visit conditional on its price, income and other variables of interest. The individual's problem when facing recreational decisions can be summarized by the following utility maximization problem (Phaneuf and Requate, 2016):

$$\max_{x,z,l} U(x,z,l,q)\ \ s.t.\ wT = z + (c + wt)x + wl \tag{1}$$

where the individual maximizes his or her utility by choosing the number of visits to the site (x) and the consumption of both non-recreational market goods (z) and leisure time (l) subject to time and budget constraints (w is the wage rate, t is the time needed for the visit, c is the cost to reach the site, T is the total time available). The model can be further developed by relaxing some of the assumptions that are implicit in its basic formulation, namely the single purpose nature of the visit, an exogenously determined onsite time, the impossibility to adjust the trip decision, an opportunity cost of time based on the wage rate, and the absence of utility/disutility from travelling to the site (Phaneuf and Requate, 2016).

3.3. Data description

3.3.1. Recreation data

This work uses an existing dataset from the BlueHealth International Survey, an international online study conducted in four waves between June 2017 and April 2018 in 18 countries around the world, whose aim was to investigate people's recreational habits and the effects of blue spaces on physical and psychological health (Grellier et al., 2017)[8]. The study resulted in a final number of 18,838 respondents, reached by the market research company YouGov through their registered panels of participants. Data collection was performed by means of stratified sampling of geographical regions by different combinations of age and sex with the aim of recruiting approximately 250 responses per country per wave. The publicly available version of the dataset includes information for 11 European countries on the following topics: subjective well-being, frequency and perception of visits to natural environments, features of recently visited blue spaces, the effect of bathing water signage on recreational habits, the participant's health status and demographics (Elliott and White, 2022)[9]. A full description of the methodology applied to run the survey can be found in Elliott and White (2020).

This data was subsequently used by Börger et al. (2021), who applied the TCM to examine recreational visits to blue spaces in 14 EU Member States through a combined TCM and contingent behavior approach. The aim of Börger et al. (2021) was to understand recreationists' habits and how these would be impacted by

[8] The BlueHealth International Survey data was created using funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 666773.

[9] Unlike the dataset used by Börger et al. (2021), the public version- deposited in the UK Data Service- does not report information for respondents from the following countries: Finland, Ireland and Portugal. In the analysis we do not consider respondents from Czech Republic because of the lack of marine fisheries in its territory.

changes in perceived water quality, as well as to provide an economic assessment of the value attributed to a visit. In their analysis, the recreational good is a blue space, namely urban inland (e.g. urban canals), rural inland (e.g. waterfalls), urban coastal (e.g. piers) and rural coastal sites (e.g. cliffs) (Elliott and White, 2020, p. 15). Since our interest lies on the influence of marine fishing activities on recreation, we filter the dataset keeping only observations pertaining to coastal environments.

Given the advantages of a dataset with such wide coverage and unusually high number of observations, we use the public version of this dataset to investigate how the presence of a fishing fleet affects individuals' choice of participation in coastal recreation. As in Börger et al. (2021), our dependent variable is the number of trips to the last visited coastal environment in the four weeks preceding the administration of the survey. The explanatory variables are the demographic and socioeconomic characteristics of the respondent (country, sex, age, education, marital status, income, swimming competence and dog ownership), the period in which the questionnaire was compiled, the type of environment visited, the purpose of the trip and the travel cost. We expand Börger et al. (2021)'s analysis by including both the opportunity cost of travelling time, and fisheries-specific variables among the regressors.

With regard to the dataset construction, we follow the same inclusion criteria described in Börger et al. (2021) to get what they call the final "TCM sample" (a thorough description of each step is provided in the Supplementary Material section A.3 of their article). This implies the exclusion of visits *i*) which were entirely for other purposes than visiting the site, *ii*) not starting from home, *iii*) with a one-way road distance of more than 1,000km and *iv*) with unrealistic combinations of travel mode and distance travelled/visit frequency. Respondents who declared on average more than two visits per day over a four- week period and those who provided unreliable home and visit locations are also excluded. Due to the exclusion criteria, the large majority of trips under analysis is likely to be day visits (i.e., with a duration of less than a day, beginning and ending at the same location) rather than overnight trips (i.e., with a duration of more than one day). Concerning the construction of the travel cost variable, we apply the same country-specific per-km costs for each mode of transport as in Börger et al. (2021), namely: personal motorized transport, bicycle, train, taxi, hired car, ferry, other (for walking, running and jogging the cost was set to zero) (Supplementary Material section B.2)[10]. If the visit involved the use of a personal motorized transport (e.g. car, van, motorbike), taxi or hired car, the travel cost expenses are shared among the adults taking part in the visit.

Since not accounting for the value of time can lead to an underestimation of consumer surpluses (Ward and Beal, 2000), in this paper we expand the work by Börger et al. (2021) by including the opportunity cost of travel time, a frequent practice in TCM studies. In order to compute the opportunity cost of time for each visit, the travelling time to reach the coastal environment is extracted dividing the home-site distance by the average

[10] Due to privacy reasons, any information about the home address of respondents (e.g. the geographic coordinates, latitude and longitude, or postal codes) has been removed from the dataset. We were thus not able to compute the route from the home location to the site, but an additional variable reporting the travelling distance in kilometers (Supplementary Material section A.2) from the home address to the blue space visited has been generously provided by the dataset creators Lewis Elliott and Mathew White.

speed of each mode of transport. These values and respective sources are provided in the Appendix (Table A1). The opportunity cost of travel time is then obtained by multiplying the round-trip time by one third of the hourly income of the respondent, following an established practice in the travel cost literature (Cesario, 1976; English et al., 2018; Ward and Beal, 2000). The income per respondent is divided by the average number of annual hours worked per country (OECD, 2022) to retrieve the respondent's hourly income.

A limitation of individual TCM applications is their inability to properly account for substitution effects across recreational sites (Perman et al., 2003). On the contrary, the random utility TCM is considered to be the most appropriate model when the visitor's choice involves multiple locations, as it allows to identify the trade-offs between money (trip cost) and other characteristics varying among sites (Parsons, 2003; Phaneuf and Smith, 2005). The random utility TCM model more faithfully accounts for substitution effects by identifying why a site is preferred over another given its characteristics and travel costs (Phaneuf and Requate, 2016). However, the random utility TCM is not compatible with our dataset due to missing information necessary to calculate the travel cost to other sites in the choice set (see Footnote 10).

3.3.2. Fisheries data

In this paper, the underlying variable of interest is the attractiveness of a harbor, as we hypothesize that attractive fishing harbors draw visitors. However, the attractiveness of a harbor is a latent variable that we cannot properly measure. It is also unclear which particular feature of a fishing harbor attracts visitors. To measure attractiveness, we account for various characteristics of the fishing fleet registered at each harbor given available data. We collect fishing fleet data from the European Commission's Fleet Register for the year of 2018.[11] We define SSF vessels as those with a length under 12 meters and using passive gears (STECF, 2021).[12] Coordinates for each fishing harbor are collected from Maratlas and then matched with the 2018 fishing fleet data using harbor codes.[13] The result is a set of six variables representing capacity of fishing harbors, namely number of vessels, power and tonnage, for either LSF or SSF vessels. If a harbor is located within a 5-kilometer radius, then the six fishery variables take the capacity values that the Fleet Register assigns to that harbor (and zero otherwise). To test for presence rather than capacity of the fishing fleet, we also create a dummy variable that takes value 1 if a fishing harbor is within a five-kilometer radius of the chosen coastal environment (i.e. the recreational destination). The distance threshold was set at five kilometers because it allows the fishing harbor to be within a walkable distance from the visited site. However, sensitivity analysis is provided in the Discussion (Section 5.1) by varying this threshold.

The descriptive statistics are summarized in Table 1. As shown by the low mean of the fishery-related variables, the majority of respondents visited coastal environments more than 5 kilometers away from a fishing harbor. By controlling for different attributes, we wish to capture the attractiveness of a fishing harbor and

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[11] Data was collected from: https://webgate.ec.europa.eu/fleet-europa/search_en
[12] The following acronyms were used to identify vessels that use a passive gear: LNB, LNS, GNS, GND, GNC, GTR, GTN, FPO, LHP, LHM, LLS and LLD (Macfayden et al., 2011).
[13] Data was collected from: https://maratlas.discomap.eea.europa.eu/arcgis/rest/services/Maratlas

investigate which features affect the demand for recreational visits. Descriptive statistics of the non-fisheries variables included in the model can be found in Table A2.

Table 1 – Summary statistics of subsets of variables included in the models.

Variable	Full sample (after exclusion criteria)					TCM sample*				
	Obs	Mean	Std. Dev.	Min	Max	Obs	Mean	Std. Dev.	Min	Max
Fishery variables										
Harbor dummy	1,728	0.38	0.49	0	1	1,128	0.38	0.48	0	1
Number of LSF vessels	1,661	7.46	19.08	0	178	1,128	8.37	20.16	0	178
Tonnage of LSF vessels (GT)	1,661	597.55	1,764.43	0	11,133	1,128	625.70	1,772.49	0	11,133
Power of LSF vessels (kW)	1,661	1,780.89	4,708.39	0	40,119	1,128	1,954.96	4,966.36	0	40,119
Number of SSF vessels	1,661	33.93	100.69	0	595	1,128	36.65	104.36	0	595
Tonnage of SSF vessels (GT)	1,661	67.47	194.33	0	1,138	1,128	72.40	200.65	0	1,138
Power of SSF vessels (kW)	1,661	925.51	3,034.59	0	25,632	1,128	986.44	3,104.54	0	25,632
Other variables										
Number of visits to this blue space in the last 4 weeks	1,728	4.23	5.82	1	56	1,128	4.27	5.75	1	56
Income (€)	1,507	17,670	11,344	1,498	43,922	1,128	18,266.06	11,548	1,498	43,922
Travel Cost (€)	1,728	10.58	23.73	0	240	1,128	10.78	24.01	0	240

*This is the final sample. Observations with missing values for one or more variables are excluded from the regression

Table 2 – Truncated Negative Binomial model estimation results.

Variable	Model 1 Number of visits to this blue space in the last 4 weeks	Model 2 Number of visits to this blue space in the last 4 weeks	Model 3 Number of visits to this blue space in the last 4 weeks
Travel cost	-0.0483***	-0.0483***	-0.0484***
	(-9.45)	(-9.45)	(-9.46)
Harbor dummy	0.255*	0.168	0.256**
	(1.91)	(1.30)	(1.99)
Number of SSF vessels	0.00327***		
	(3.38)		
Number of LSF vessels	-0.0163***		
	(-3.10)		
Tonnage of SSF vessels		0.000924**	
		(2.34)	
Tonnage of LSF vessels		-0.0000716*	
		(-1.70)	
Power of SSF vessels			0.0000970***
			(3.50)
Power of LSF vessels			-0.0000586***
			(-3.11)
Constant	-1.470	-1.404	-1.335
	(-1.08)	(-1.03)	(-0.98)
# of other parameters			
lnalpha	1.303***	1.334***	1.306***
	(5.72)	(5.73)	(5.73)
N	1128	1128	1128
AIC	4917.1	4924.1	4916.7

BIC	5133.3	5140.3	5132.9
***, **, * denote significance at the 1, 5, and 10% levels, respectively. Standard errors in parentheses.			

3.4. Results

To model the demand curve for recreational visits, we use the Truncated Negative Binomial regression model, a common procedure in the TCM literature (Du Preez and Hosking, 2011; Twerefou and Ababio, 2012; Zhang et al., 2015)[14]. The Truncated Negative Binomial model allows for both overdispersion (i.e., the conditional variance of the underlying distribution of trips can exceed the conditional mean) and zero-truncation (i.e., only respondents who made at least one visit to a coastal environment in the previous four weeks are considered). Maximum likelihood estimation is used to obtain the coefficients of the model[15].

3.4.1. Estimation results

We run the regression for three different specifications by changing the measure of the fishing capacity of both SSF and LSF vessels. These variables indicate the number of vessels, the total tonnage (measured in Gross Tonnage) and the total power (measured in Kilowatts) of the vessels registered in the harbor, which are highly correlated. In Table 2 we present only the estimates for the fishery variables and the travel cost. The full regression output including all control variables can be found in Table A3. The likelihood-ratio chi-square test shows that the overdispersion parameter alpha is different from zero at the 95% confidence level in the three models under consideration. This implies that the use of the (zero-Truncated) Negative Binomial regression should be preferred to Poisson, whose assumption of equidispersion is here violated (Haab and McConnell, 2002).

First, it emerges that the sign associated with the coefficient for the travel cost variable is negative, as dictated by economic theory. The travel cost is always significant at the 1% level across the three models. This confirms the notion that individuals having higher travel expenses take less visits to the coastal environment reported in the survey. When looking at the fishery variables, it emerges that the dummy (i.e., taking value 1 if there is a fishing harbor in the proximity of the visited site) is significant in Models 1 and 3. Such a variable is here used as fishing presence regardless of capacity, with the aim of testing whether if the presence of a harbor hosting at least one fishing vessel suffices to attract visitors. The results indicate that the presence of a fishing harbor is in itself an attractive feature for coastal spaces. However, as suggested by the statistical significance of the other fishing variables, the capacity of the fleet also plays a role in the participation decision.

The estimated coefficients providing a continuous measure of fishing capacity suggest that the composition of the fleet registered at the harbor can influence the choices of recreationists. In particular, we

[14] Our approach diverges from the modelling approach adopted by Börger et al. (2021) by omitting analysis of Contingent behavior responses from the experimental section of their survey.
[15] Negative binomial regression belongs to the category of generalized linear models, where the dependent variable represents the count of occurrences of an event.

see that the variables associated with SSFs are all positive and statistically significant across the different specifications. Notwithstanding this, the support in favor of the hypothesis that an increase in the capacity of SSFs positively impacts visitation rates is not equal across specifications. When attractiveness of a harbor is measured in terms of the total tonnage of these vessels (Model 2), the corresponding coefficient is positive but only statistically significant at the 5% level. Stronger evidence backing the recreational potential of SSFs can be found when the capacity of SSF vessels is described by their total number or power: in Models 1 and 3 these variables are significant at the 1% level.

Opposite results emerge when we focus on the variables indicating the industrial vessels registered at the harbor. Indeed, it appears that the presence of LSFs has a negative influence on the frequency of visits to blues spaces. This argument holds in all the three models under consideration, especially when capacity is measured through the number of vessels or their total power (statistically significant at the 1% level in Model 3). Concerning the statistical fit of the models, no major differences are found. Nevertheless, Model 3 shows both the lowest AIC (Akaike's information criterion, 4916.7) and BIC (Bayesian information criterion, 5132.9) values, meaning that describing the fishing capacity of SSF and LSF vessels through their total engine power outperforms the use of total tonnage or number of vessels as a unit of measurement. Based on these results, we could argue that the activity of SSFs tends to impact visitation positively, while LSFs have a negative effect.

3.4.2. Welfare analysis

Using these estimates, we calculate the welfare effects of changes in fishing capacity by estimating the changes in Consumer Surplus (CS) derived by a decrease in the capacity of SSF vessels. In a (Zero-Truncated) Negative Binomial model, the variation in CS due to a change in one of the explanatory variables is given by (Hanley et al., 2003):

$$\Delta CS_{i=} \frac{exp(\sum_k \gamma X_k + \delta Z_i^* - \alpha TCost_i)}{\alpha} - \frac{exp(\sum_k \gamma X_k + \delta Z_i - \alpha TCost_i)}{\alpha}, \qquad (2)$$

where X is the vector of k explanatory variables with γ coefficient, Z_i^* indicates the change in the capacity of SSF vessels from the baseline Z, δ is the associated coefficient and α is the country-specific travel cost coefficient. The formula indicates that the change in CS for individual *i* after a change in one of the explanatory variables is equal to the variation in the predicted number of visits divided by the travel cost coefficient (Johnstone and Markandya, 2006). Using the whole TCM sample (1128 observations), we use Equation 2 to compute the change in CS for each respondent due to a one unit decrease in the three fishing capacity indicators. Moreover, in order to inspect CS variations at the national level, we rerun Models 1, 2 and 3 separately for a subset of countries, namely Greece, Spain and Sweden.[16] The welfare change results, obtained by applying the newly estimated coefficients to Equation 2, are included in Table 3.

We also calculate the potential welfare loss in a hypothetical scenario characterized by the complete removal of the small-scale fleets registered at the harbors covered by the sample. Setting the number of SSF

[16] Only these three countries were considered due to convergence issues with the Truncated Negative Binomial model.

vessels equal to zero, the difference in the number of visits to the coastal space- divided by the travel cost coefficient- indicates that the monetary value of having an SSF fleet in the proximity of coastal sites is far from negligible. If we multiply such figures by the average number of individual visits to coastal spaces during the year and the 2017/2018 national population (reported in Börger et al. (2021)), we obtain the total recreational value of SSFs (see Table A4). We find substantial recreational values of SSFs in aggregate terms, ranging from 49.4 million EUR in Sweden and 189.4 million EUR in Spain to nearly 4 billion EUR in Greece.

3.5. Discussion

The results suggest that the total economic value of SSFs includes substantial recreational benefits. Despite their variation in magnitude and statistical significance, the fishery variables included in the model indicate a positive effect of SSFs on the attractiveness of coastal sites. This conclusion holds using total number of vessels, power or tonnage as alternative indicators of fishing capacity, as well as for the presence of a fishing port. Here we infer on the robustness of our results when changing some assumptions of our analysis. Overall, we find that SSF capacity, as well as the presence of a fishing harbor, positively affect the recreational value of a trip.

3.5.1. Model specification and sensitivity analysis

First, we recognize the possibility of having non-linear marginal effects of changes in the fishing fleet on the frequency of visits. Therefore, we allow for the possibility of having decreasing or increasing marginal effects of the fishery variables by re-estimating the three models with the addition of squared terms for both number of vessels, tonnage and power. However, they do not yield economically significant results: the sign of the coefficients confirms the results from Models 1, 2 and 3 (a positive relationship between visits and SSFs and a negative one when LSFs are considered) with no tipping point. Moreover, the quadratic models do not provide higher statistical fit when considering the AIC and BIC criteria. The results are reported in the Appendix (Table A5). In addition, we recognize the arbitrariness of choosing a five-kilometer distance as the threshold to define the presence of a fishing harbor in the proximity of the visited site. For this reason, we rerun Models 1, 2 and 3 by increasing and decreasing the walkable distance by two kilometers. The results, shown in Tables A6 and A7 – respectively for the three kilometers and the seven kilometers thresholds-, tend to confirm the sign and significance of the coefficients associated with the variables previously obtained and reported in Table 2. However, the influence of the harbor dummy appears to be more subject to the threshold choice, to the extent that it looses significance when the radius is broadened to seven kilometers. Contrarily, the positive effect of SSFs on recreation is robust to both specifications.

Concerning the variations in CS estimates, the results displayed in Table 3 indicate that these values differ among Member States. The scope of this paper is not to explain differences across countries. Apart from differences in income among the population, it goes without saying that reductions in fishing capacity would have a higher impact in coastal areas characterized by a higher frequency of either fishing harbors, SSFs vessels or recreational visits to marine sites. This explains why in Greece- where the recreational value of artisanal vessels is relatively smaller than Spain- the CS reduction due to the loss of all national SSFs (Table A4) would be considerable (see Table A9 for a descriptive summary of the distribution of SSF vessels in the coastal sites included in the survey). This is due to the combined effect of a strong presence of artisanal fisheries along the coastline and high frequency of recreational visits to marine locations by the Greek population. In addition, there might be other latent factors determining the relevance of the fishing sector in the countries under analysis and thus influencing recreational behavior. Further research could potentially investigate this issue by analyzing the correlation between the societal value of SSFs in European countries and the local social, historical and cultural role of fisheries. Nevertheless, the results for our multi-country TCM sample highlight the importance that European citizens engaging in outdoor recreation place on the presence of SSFs in coastal sites.

We could have concentrated the CS analysis on the effects of an addition in fishing capacity rather than a decrease. The estimates for one-unit increase in both number of vessels, tonnage and power are very close in magnitude (but with opposite sign) to the ones showed in the paper for a one-unit decrease. Such an approach could be used in a cost-benefit analysis comparing, for instance, the subsidies that the EMFF grants for the acquisition of SSF vessels to young fishermen (European Parliament, 2021) with the recreational benefits that these vessels would generate. However, we decided to focus on the consequences on recreation of capacity reductions because it is more realistic to expect a declining trend for SSFs in the EU context. The latest Annual Economic Report on the EU Fishing Fleet clearly identifies the complexities currently experienced by the small-scale segment of the fleet, which constituted 76% of the active fleet and 50% of the engaged crew as of 2020: -21% in Full Time Equivalents and a reduction in net profit larger than 60% between 2018 and 2020, with SSFs being especially affected by the value chain disruption due to COVID-19 (STECF, 2022). The previous discussion on multifunctionality suggests that the consequences of small-scale fishers leaving the sector would not be limited to a decrease in landings. Recreational habits in European coastal areas could be negatively affected as well.

To control for nearby economic activity shaping the recreational appeal of the visited sites, we include two additional variables describing the socio-economic condition of the area visited by the respondent, in order to isolate potentially confounding factors. Using the geographic coordinates of the visit, we retrieve the 2018 local GDP and population density of corresponding the NUTS 3 level from Eurostat (Eurostat, 2023a; Eurostat, 2023b) and complemented with UK data (Office for National Statistics, 2023). The values are later divided by the territorial average - to account for the relative importance of the region when compared with the NUTS 3's average - and included among the regressors in Model 1. The negative coefficients associated to the relative GDP and population density (Table A8) indeed suggest that recreational visits in coastal environments may be discouraged by the presence of intense economic activity in the area. It is worth stressing that the previously obtained results concerning the positive effect of SSFs are robust to these additional model specifications.

Table 3 – Change in Consumer Surplus (CS) for a one unit decrease in SSF capacity.

Individual ΔCS per visit (€)	**Observations**	**Number of SSF vessels N-1**			**Tonnage of SSF vessels GT-1**			**Power of SSF vessels kW-1**		
	N	Mean	Std.Dev.	95% Conf. Interv.	Mean	Std.Dev.	95% Conf. Interv.	Mean	Std.Dev.	95% Conf. Interv.
TCM sample	1,128	-0.05	0.09	[-0.06,-0.04]	-0.01	0.02	[-0.02,-0.01]	-0.002	0.003	[-0.002,-0.001]
Greece	301	-0.06	0.1	[-0.07,-0.05]	-0.02	0.03	[-0.02,-0.01]	-0.002	0.003	[-0.002,-0.001]
Spain	159	-0.08	0.11	[-0.09,-0.06]	-0.02	0.03	[-0.02,-0.02]	-0.002	0.003	[-0.003,-0.002]
Sweden	65	-0.07	0.1	[-0.09,-0.06]	-0.02	0.03	[-0.02,-0.02]	-0.002	0.003	[-0.003,-0.002]

3.5.2. Study limitations

As stated in the Data description (Section 3.3), our variable of interest is the attractiveness of a harbor. We have used presence and capacity of nearby fishing harbors as measures of harbor attractiveness. A related discussion in the literature is the “virtual fishery hypothesis”. Andersson et al. (2021) raised the argument that the identity of a place as a fishing village could be more influential than the actual fishing capacity in determining the level of attractiveness of coastal sites. As noticed by Waldo et al. (2023) during the interviews with local stakeholders in Sweden, while the identification as a fishing village positively affects tourism, there is uncertainty whether an active fishery (with vessels traffic by the harbor and catch unloading) is needed. In other words, a "virtual" fishing industry through imagery and symbolism (Brookfield et al., 2005) may be more valued than the concrete presence of fishing vessels.

Our data is not adequate to infer on this hypothesis. We account for a harbor dummy in order to test whether the presence of a fishing fleet matters- rather than its capacity- and find some support for the intuition that keeping at least one or few vessels registered at the harbor is an effective way to attract visitors. However, this measure does not fully capture what the fishing image of a harbor is. In addition, both the capacity and the composition of the fleet seem to influence recreational behavior, meaning that visitors are not indifferent to the most visible aspects of a fishing harbor (i.e. the vessels). We also suggest that, in order to understand whether the fishery-related historical image of a place is more attractive that its current fleet, the association of capacity with effort statistics (ideally as a time series) would help differentiate between thriving harbors and sites where the fishing activity is marginal or declining. Where possible, further insights could be provided by the inclusion of other relevant factors contributing to build the image of a fishing town, such as the presence of fishing museums, fishing markets or the promotion of marketing strategies capitalizing on the fishing tradition of the community, for instance through pictures in postcards and brochures. The negative coefficient associated to LSFs variables could correspondingly capture other environmental factors (e.g. noise pollution) that have not been included in the analysis.

Moreover, while we look at vessels registered at the harbor, it is likely that larger vessels will spend more time on sea and therefore will not be seen by recreationists. Similarly, it is also possible that fishing vessels registered in one harbor will operate in a different fishing harbor. However, the use of official data from the Fleet Register was the only way to get detailed information of the fishing activity that is supposed to take place in European harbors. Further valuation studies focusing at the regional level or even considering only one coastal site may include other measures of fishing effort we do not possess information over.

Our use of a pooled single site travel cost model is motivated by the available data (i.e. inability to calculate travel costs to alternative sites due to data privacy reasons). While the use of this model may not reflect the best practices in the recreation literature (Lupi et al., 2020), it is a large dataset with unusual large coverage, which presents other important advantages such as the ability to generalize the results to a large fraction of EU countries. We estimate the recreational value of SSFs across different countries, and show that this value is substantial in the ten countries under analysis. Future work focusing on the recreational benefits of SSFs could apply the random utility TCM, which accounts for site substitution, in those contexts where enough information is provided to construct the choice set[17].

3.6. Conclusions

The present study is based on the application of the TCM to analyze the relationship between frequency of visitation to European coastal environments and the capacity and presence of a fishing harbor in the proximity of the visited locations. Using three different indicators of fishing capacity (number of vessels, total tonnage and engine power) and controlling for a number of other relevant variables normally included in the TCM literature, the results highlight the different potential of SSFs and LSFs in determining the frequency of visits to coastal spaces. While an increase in the capacity of the former segment of the fleet is supposed to attract visitors, it seems that respondents have been discouraged by the presence of industrial fisheries. In summary, the existence of a fishing harbor is by itself an appealing amenity, but the capacity of the whole fleet registered at the harbor also plays a role. Investigating the welfare effects of reductions in fishing capacity, we compute the hypothetical variations in CS per visit after a one vessel reduction in the small-scale segment of the fleet in the harbors covered by the survey, obtaining an average value of -0.05€.

This is one of the first papers to empirically support the claim that fishing harbors attract local visitors. The recreational value lost due to a hypothetical withdrawal of SSF vessels is considerable (see Table A4): 49.4 million EUR in Sweden, 189.4 million EUR in Spain and 3.9 billion EUR and Greece. It ultimately emerges that the total recreational benefits of SSFs far exceed their market value- measured in terms of gross value of landings in the year 2018- in each of these three countries (STECF, 2020). These are external non-

[17] Although the controversy over the existence and inclusion of substitute sites in TCM has been raised for both cultural (Bedate et al., 2004) and nature-based recreation (Mayer and Woltering, 2018), it is acknowledged that the omission of substitution possibilities in revealed preference studies could lead to biased WTP estimates (Cutter et al., 2007). Individual TCM applications are limited in their ability to capture substitution effects, and the random utility TCM is considered to be more appropriate when the visitor's choice involves multiple locations, as it allows to identify the trade-offs between money (trip cost) and other characteristics varying among sites (Parsons, 2003; Phaneuf and Smith, 2005).

market benefits beyond food provisioning and justify the allocation of some economic support for the SSF sector. Similarly, Waldo et al. (2023) also claim that the presence of positive externalities on tourism might motivate the subsidization of SSFs in particularly picturesque areas, provided that the cost of maintaining fishing-related components of local cultural heritage does not exceed their benefits.

The positive effect of the SSFs variables on trip frequency provides clear support for the inclusion of non-market value estimates in bioeconomic modelling of fisheries management, especially in those contexts where effort needs to be split among different fishing fleets (e.g. small-scale and industrial). This argument is not new. For instance, in his bioeconomic model incorporating the interactions between fisheries and tourism, Bull (2007) assumed that "the model should allow for a positive interaction between tourism and small-scale fishing harbors, but a negative interaction between tourism and large-scale ones". Consideration of the multiple dimensions of fisheries externalities has also been advocated for the development of bioeconomic models expanding the traditional focus on the direct use value of single species fisheries (Kronbak et al., 2013), hence responding to the increasing need for ecosystem-based management of marine resources (Ryan et al., 2014). It follows that socially efficient fisheries management should be based on the assessment of the broad spectrum of externalities (both positive and negative) associated with fishing activities. The recreational value of SSF vessels can be included among the positive externalities.

It is hence important to remark that, focusing on the recreational value of a small-scale fleet, this article looks at only one component of the total economic value of the fishing sector. We argue that the whole spectrum of externalities (both positive and bad) related to the fishing industry should be assessed in order to realize its contribution to societal welfare. This is especially important in the case of the impacts of fishing practices on marine ecosystems, since the magnitude of these externalities is far from negligible (Dayton et al., 1995; Jones, 1992; Pennino et al., 2011), to the extent that society may be willing to let the fishing sector experience a decrease in revenue in order to have stricter measures for ecosystems preservation (Aanesen et al., 2015). However, the positive results emerged in this study- together with the numerous evidence supporting the notion that SSF vessels have a less harmful impact on the ecosystem than industrial vessels (Lowitt et al., 2020; Pascual-Fernández et al., 2020; Sartor et al., 2019)- suggest that potential additional reductions of fishing capacity in the EU should be also confronted with the extensive application of non-market valuation methods to the small-scale segment of the fishing fleet.

3.7. Appendix

Table A1 – Assumed values for the average speed of the different modes of transport declared by the respondents to the survey.

Mode of transport	**Speed (*km/h*)**	**Source**
Personal motorized transport, hired car	60	(Czajkowski et al., 2014; Zhang et al., 2015)
Walk	4	(Saneinejad et al., 2012)
Bicycle	16	(Saneinejad et al., 2012)

Train	100	(Lidén and Joborn, 2016)
Ferry	25	(Jørgensen and Solvoll, 2018)
Running, jogging	8	Personal assumption
Bus	60	Personal assumption
Taxi	60	Personal assumption
Other	30	Personal assumption

Table A2 – Summary statistics of the other categorical variables included in the models.

Variable	**Full sample**		**TCM sample**	
	Frequency (*N*)	Percentage (*%*)	Frequency (*N*)	Percentage (*%*)
Country				
Bulgaria	93	5.38	64	5.67
Estonia	120	6.94	63	5.59
France	118	6.83	76	6.74
Germany	24	1.39	10	0.89
Greece	441	25.52	301	26.68
Italy	269	15.57	209	18.53
Netherlands	114	6.6	68	6.03
Spain	204	11.81	159	14.1
Sweden	156	9.03	65	5.76
United Kingdom	189	10.94	113	10.02
Wave				
Jun-17	498	28.82	331	29.34
Sep-17	460	26.62	309	27.39
Dec-17	373	21.59	232	20.57
Mar-18	397	22.97	256	22.7
Sex				
Female	864	50.00	538	47.7
Male	864	50.00	590	52.3
Age				
18-29	266	15.39	158	14.01
30-39	324	18.75	216	19.15

40-49	344	19.91	234	20.74
50-59	340	19.68	231	20.48
60+	454	26.27	289	25.62
Education				
Did not complete primary education	5	0.29	4	0.35
Completed primary education	73	4.22	45	3.99
Completed secondary education	665	38.48	441	39.1
Completed higher education	985	57	638	56.56
Marital status				
Married, civil union, cohabiting	1,094	63.31	871	77.22
Single, separated, divorced, widowed	553	32	230	20.39
Neither of these	64	3.7	24	2.13
Prefer not to answer	17	0.98	3	0.27
Dog ownership				
No	1,180	68.29	728	64.54
Yes	548	31.71	400	35.46
Competence at swimming				
No	896	51.85	589	52.22
Yes	832	48.15	539	47.78
Water quality				
Poor	103	5.96	67	5.94
Sufficient	328	18.98	210	18.62
Good	847	49.02	543	48.14
Excellent	450	26.04	308	27.3
Type of environment				

Harbor or marina	248	14.35	152	13.48
Open sea	96	5.56	63	5.59
Pier	68	3.94	41	3.63
Rocky or stony shore	68	3.94	48	4.26
Salt marsh, estuary or lagoon	14	0.81	8	0.71
Sandy beach or dunes	427	24.71	287	25.44
Sea cliffs	29	1.68	21	1.86
Seaside promenade	778	45.02	508	45.04
Purpose of the visit				
Entirely to visit this place	1,130	65.39	749	66.4
Partly to visit this place and partly to do something else	598	34.61	379	33.6

Table A3 – Truncated Negative Binomial model estimation results, including only control variables.

Variable	**Model 1** Number of visits to this blue space in the last 4 weeks	**Model 2** Number of visits to this blue space in the last 4 weeks	**Model 3** Number of visits to this blue space in the last 4 weeks
Country (ref: Bulgaria)			
Estonia	0.0661	0.161	0.0851
	(0.20)	(0.48)	(0.26)
France	0.414	0.343	0.200
	(1.20)	(1.00)	(0.58)
Germany	-0.478	-0.503	-0.610
	(-0.73)	(-0.76)	(-0.93)
Greece	0.412*	0.394	0.348
	(1.68)	(1.61)	(1.42)
Italy	0.0889	-0.0368	-0.0822
	(0.31)	(-0.13)	(-0.30)
Netherlands	-0.650*	-0.594	-0.703*
	(-1.67)	(-1.49)	(-1.84)
Spain	0.443	0.422	0.321
	(1.49)	(1.43)	(1.11)
Sweden	0.461	0.463	0.349
	(1.13)	(1.14)	(0.88)
United Kingdom	0.451	0.361	0.265
	(1.41)	(1.15)	(0.86)
Wave (ref: Jun-17)			
Sep-17	0.169	0.168	0.190
	(1.20)	(1.18)	(1.34)

Dec-17	-0.236	-0.259*	-0.225
	(-1.55)	(-1.70)	(-1.48)
Mar-18	-0.0423	-0.0508	-0.0220
	(-0.28)	(-0.34)	(-0.15)
Sex (ref: Female)			
Male	0.128	0.123	0.131
	(1.19)	(1.13)	(1.21)
Age (ref: 18-29)			
30-39	0.401**	0.380*	0.423**
	(1.99)	(1.87)	(2.08)
40-49	0.216	0.207	0.232
	(1.10)	(1.04)	(1.17)
50-59	0.297	0.263	0.281
	(1.52)	(1.34)	(1.43)
60+	0.663***	0.648***	0.679***
	(3.38)	(3.28)	(3.44)
Education (ref: Did not complete primary education)			
Completed primary education	0.534	0.551	0.537
	(0.62)	(0.63)	(0.62)
Completed secondary/further education (up to 18 years of age)	0.427	0.381	0.421
	(0.52)	(0.46)	(0.51)
Completed higher education (e.g. university degree or higher)	0.625	0.592	0.628
	(0.75)	(0.71)	(0.76)
Marital status (ref: Prefer not to answer)			

Married, in a civil union, or living with your partner (cohabiting)	0.411	0.327	0.316
	(0.42)	(0.34)	(0.33)
Single, separated/divorced/civil union dissolved or widowed/civil partner died	0.436	0.360	0.360
	(0.45)	(0.37)	(0.37)
Neither of these	0.552	0.490	0.461
	(0.53)	(0.47)	(0.44)
Dog ownership			
Yes	0.351^{***}	0.332^{***}	0.348^{***}
	(3.07)	(2.90)	(3.05)
Swimmer			
Yes	0.183^{*}	0.210^{*}	0.198^{*}
	(1.71)	(1.94)	(1.85)
Water quality (ref: Poor)			
Sufficient	-0.126	-0.0889	-0.138
	(-0.52)	(-0.37)	(-0.57)
Good	0.145	0.148	0.113
	(0.63)	(0.64)	(0.49)
Excellent	0.333	0.395	0.338
	(1.39)	(1.64)	(1.41)
Type of environment (ref: Harbor or marina)			
Open sea	0.0729	0.128	0.0827
	(0.28)	(0.48)	(0.31)
Pier	-0.0927	-0.0562	-0.108
	(-0.31)	(-0.19)	(-0.36)

Rocky or stony shore	-0.126	-0.0250	-0.0823
	(-0.44)	(-0.09)	(-0.28)
Salt marsh, estuary or lagoon	-0.923	-0.892	-0.927
	(-1.51)	(-1.46)	(-1.52)
Sandy beach or dunes	-0.0664	-0.0160	-0.0782
	(-0.37)	(-0.09)	(-0.43)
Sea cliffs	-0.783*	-0.679*	-0.727*
	(-1.91)	(-1.66)	(-1.78)
Seaside promenade	-0.0646	0.00428	-0.0396
	(-0.39)	(0.03)	(-0.24)
Purpose (ref: Partly to visit this place and partly to do something else)			
The purpose of my journey was entirely to visit this place	0.0560	0.0401	0.0687
	(0.47)	(0.33)	(0.58)
Income	0.0000106	0.0000117	0.0000124
	(1.33)	(1.45)	(1.55)
Constant	-1.470	-1.404	-1.335
	(-1.08)	(-1.03)	(-0.98)
/			
lnalpha	1.303***	1.334***	1.306***
	(5.72)	(5.73)	(5.73)
N	1128	1128	1128
AIC	4917.1	4924.1	4916.7
BIC	5133.3	5140.3	5132.9

***, **, * denote significance at the 1, 5, and 10% levels, respectively. Standard errors in parentheses.

Table A4 – Change in Consumer Surplus (CS) in a hypothetical scenario where all SSF vessels are removed.

Country	**Individual ΔCS (€/visit)**			**Annual visits to marine* spaces**	**Adult population**	**Total ΔCS (€)**
	Mean	Std.Dev	95% Confidence Interval	N	(in 1000)	(in €1mln)
TCM sample	-3.41	10.95	[-4.12,-2.70]	19.4	300,243	-19838.5
Greece	-8.63	18.76	[-10.42,-6.84]	51.8	8,861	-3956
Spain	-0.28	0.56	[-0.34,-0.23]	17.4	38,295	-189.4
Sweden	-0.20	0.34	[-0.24,-0,16]	31.2	7,997	-49.4

*Average annual visits are taken from Börger et al. (2021) and multiplied by the frequency of visits to coastal blue spaces over total blue space

Table A5 – Truncated Negative Binomial model estimation results, including squared terms.

Variable	Model 1 Number of visits to this blue space in the last 4 weeks	Model 2 Number of visits to this blue space in the last 4 weeks	Model 3 Number of visits to this blue space in the last 4 weeks
Travel cost	-0.0483***	-0.0486***	-0.0482***
	(-9.44)	(-9.48)	(-9.42)
Harbor dummy	0.216	0.237	0.262*
	(1.37)	(1.54)	(1.72)
Number of SSF vessels	0.00290		
	(1.24)		
Number of SSF vessels (squared)	0.000000757		
	(0.19)		
Number of LSF vessels	-0.00980		
	(-0.80)		
Number of LSF vessels (squared)	-0.0000799		
	(-0.57)		
Tonnage of SSF vessels		0.00139	
		(1.19)	
Tonnage of SSF vessels (squared)		-0.000000309	
		(-0.28)	
Tonnage of LSF vessels		-0.000339**	
		(-2.05)	
Tonnage of LSF vessels (squared)		0.0000000338	
		(1.62)	
Power of SSF vessels			0.0000534
			(0.74)

Power of SSF vessels (squared)			0.0000000025
			(0.73)
Power of LSF vessels			-0.0000307
			(-0.73)
Power of LSF vessels (squared)			-0.00000000145
			(-0.70)
Constant	-1.445	-1.429	-1.282
	(-1.06)	(-1.04)	(-0.94)
/			
lnalpha	1.301***	1.323***	1.303***
	(5.72)	(5.73)	(5.73)
N	1128	1128	1128
AIC	4920.7	4925.2	4920.0
BIC	5147.0	5151.5	5146.3

***, **, * denote significance at the 1, 5, and 10% levels, respectively. Standard errors in parentheses,

Table A6 – Truncated Negative Binomial model estimation results (3 kilometers threshold).

Variable	Model 1 Number of visits to this blue space in the last 4 weeks	Model 2 Number of visits to this blue space in the last 4 weeks	Model 3 Number of visits to this blue space in the last 4 weeks
Travel cost	-0.0479***	-0.0481***	-0.0483***
	(-9.47)	(-9.50)	(-9.53)
Harbor dummy	0.280*	0.154	0.262*
	(1.87)	(1.08)	(1.85)
Number of SSF vessels	0.00302***		
	(2.82)		
Number of LSF vessels	-0.0165***		
	(-2.63)		
Tonnage of SSF vessels		0.00102**	
		(2.15)	
Tonnage of LSF vessels		-0.0000875	
		(-1.58)	
Power of SSF vessels			0.0000842**
			(2.50)
Power of LSF vessels			-0.0000542**
			(-2.30)
Constant	-1.415	-1.339	-1.283
	(-1.05)	(-0.99)	(-0.94)
# of other parameters			
lnalpha	1.284***	1.305***	1.306***

	(5.74)	(5.75)	(5.76)
N	1138	1138	1138
AIC	4967.1	4971.4	4969.5
BIC	5183.7	5188.0	5186.1
***, **, * denote significance at the 1, 5, and 10% levels, respectively. Standard errors in parentheses.			

Table A7 – Truncated Negative Binomial model estimation results (7 kilometers threshold).

	Model 1	**Model 2**	**Model 3**
Variable	Number of visits to this blue space in the last 4 weeks	Number of visits to this blue space in the last 4 weeks	Number of visits to this blue space in the last 4 weeks
Travel cost	-0.0481***	-0.0483***	-0.0483***
	(-9.43)	(-9.44)	(-9.46)
Harbor dummy	0.136	0.0853	0.165
	(1.04)	(0.66)	(1.29)
Number of SSF vessels	0.00252***		
	(2.95)		
Number of LSF vessels	-0.0117***		
	(-2.67)		
Tonnage of SSF vessels		0.000909**	
		(2.45)	
Tonnage of LSF vessels		-0.0000854**	
		(-2.19)	
Power of SSF vessels			0.0000883***
			(3.48)

Power of LSF vessels			-0.0000556***
			(-3.27)
Constant	-1.181	-1.197	-1.108
	(-0.87)	(-0.87)	(-0.81)
# of other parameters			
lnalpha	1.323***	1.348***	1.320***
	(5.71)	(5.72)	(5.72)
N	1116	1116	1116
AIC	4877.4	4880.1	4873.7
BIC	5093.1	5095.9	5089.5

***, **, * denote significance at the 1, 5, and 10% levels, respectively. Standard errors in parentheses.

Table A8 – Truncated Negative Binomial model estimation results (including local economic viability).

Variable	**Model 1** Number of visits to this blue space in the last 4 weeks	**Model 1** Number of visits to this blue space in the last 4 weeks
Travel cost	-0.0475***	-0.0468***
	(-7.92)	(-7.82)
Harbor dummy	0.375**	0.389**
	(2.47)	(2.53)
Number of SSF vessels	0.00313***	0.00297***
	(2.94)	(2.78)
Number of LSF vessels	-0.0151***	-0.0156***
	(-2.68)	(-2.70)
GDP NUTS 3	-0.288***	
	(-2.65)	

Population density NUTS 3		-0.0671***
		(-3.04)
Constant	0.310	-0.308
	(0.19)	(-0.19)
# of other parameters		
lnalpha	1.117***	1.101***
	(4.67)	(4.61)
N	824	804
AIC	3519.6	3434.8
BIC	3727.0	3641.1

***, **, * denote significance at the 1, 5, and 10% levels, respectively. Standard errors in parentheses.

Table A9 – Summary statistics of the distribution of SSF vessels in the sample.

Country	**Full sample**	**Number of SSF vessels**				**TCM sample**	**Number of SSF vessels**			
	Obs	*Mean*	*Std.Dev.*	*Min*	*Max*	*Obs*	*Mean*	*Std.Dev.*	*Min*	*Max*
Bulgaria	86	131.97	149.88	0	334	64	126.48	149.46	0	334
Estonia	112	9.57	14.51	0	58	63	10.97	15.81	0	58
France	117	13.22	44.59	0	359	76	15.64	49.70	0	359
Germany	22	2.05	5.85	0	23	10	2.20	5.09	0	16
Greece	437	81.73	164.27	0	595	301	86.45	169.06	0	595
Italy	262	18.06	28.54	0	123	209	19.54	29.50	0	123

Netherlands	114	4.07	6.54	0	25	68	3.74	6.23	0	15
Spain	195	1.63	3.53	0	28	159	1.69	3.59	0	28
Sweden	128	1.11	1.71	0	6	65	1.09	1.77	0	6
United Kingdom	188	5.15	16.62	0	125	113	5.71	17.83	0	125

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IV

CONNECTING CATCH PROFILES WITH EFFICIENCY: AN APPLICATION TO THE BEAM TRAWL FISHERY IN THE NORTHERN ADRIATIC SEA

4.1. Introduction

One of the most heavily exploited areas in the Mediterranean Sea is the Central-Northern Adriatic Sea (Geographical Sub-Area, GSA 17) (Bastari et al., 2016; Eigaard et al., 2017; Grati et al., 2013; Mazzoldi et al., 2014), a semi-enclosed basin characterized by an extensive continental shelf with sandy seabed and shallow waters (not exceeding 75 meters in the northern sub-basin and 150 meters in the central, with the exception of the 300 meters deep Pomo-Jabuka Pit). Considering the nutrient supply provided by the Po River and other rivers that flow through the Po-Venetian plain, the GSA 17 presents ideal conditions for trawling (Fortibuoni et al., 2017; Pranovi et al., 2015; Russo et al., 2019). The intense fishing pressure implies that, despite a slight decrease in the number of overexploited species in recent years, 73% of stocks are fished outside biologically sustainable levels (FAO, 2022).

In this paper we investigate the relationship between technical efficiency[18], catch profiles and Greenhouse Gas (GHGs) emissions in the GSA 17 by focusing on the *rapido* trawl fishery of Chioggia (Venice), which is historically considered as one of the main ports in the Mediterranean Sea (Botter et al., 2006) and represents the first port in the Adriatic Sea both in terms of landings (8,740 tonnes) and operating vessels (189) (FAO, 2022). In particular, we focus on 31 vessels from Chioggia, representing respectively 86.1% of the regional *rapido* fleet and 34.1% at the national level (as of 2019) (NISEA, 2022b). *Rapido* trawl vessels, introduced in the Veneto region in the mid-1950s, are a type of beam trawl (TBB) characterized by a cone-shaped net with a rigid metallic mouth opening that may reach a width of 4 m and glides across the sea bottom with the help of sleds, allowing fishers to target flatfish and shellfish (Armelloni et al., 2021). Generally, each vessel tows simultaneously 2-4 nets (Pranovi et al., 2000). While *rapido* is not the only trawling gear targeting demersal species in the area (Russo et al., 2020), we choose to focus exclusively on this fleet because its severe impact on the benthic community has been long acknowledged (Giovanardi et al., 1998; Pranovi et al., 2001), hence prompting increasing calls for stricter regulation of the fishery (Bastardie et al., 2017; Armelloni et al., 2021). From an economic perspective, trawling and beam trawling fisheries generate the highest revenues (around 390,000,000 €) and are the major contributors to Gross Value Added (43.3%) in the Adriatic Sea (FAO, 2022). Nevertheless, the recent increase in fuel costs has

[18] Adopting the frequently applied "output approach" in the fisheries literature (Pascoe and Tingley, 2007), technical efficiency is defined as the ability of an economic unit (*rapido* vessel) to maximize the output (catch value) given a set of inputs (time at sea and physical characteristics of the boat).

been negatively affecting the profitability of the fishery, especially considering that TBB vessels exhibit the highest incidence of fuel expenses over catch value (more than 40% in 2022) (NISEA, 2022a). An additional factor negatively impacting the economic performance of the fleet is the decline in the real price of most fish species (nominal prices not keeping up with inflation). Even if this has become more evident in 2022, by looking at the price time series of common sole (*Solea solea*, SOL), which is the most relevant species targeted by TBB in the GSA 17, a historical negative trend can be identified (-3.4% average annual change between 2010 and 2020) (STECF, 2022).

Recognising the importance of providing a deep understanding of the specific characteristics (e.g. seasonal, geographical, behavioural) of *rapido* trawlers fishing practices, a combined analysis of catch profiles and technical efficiency has relevant implications for several aspects of fisheries management, namely *i*) the relationship between local regulations and efficiency, *ii*) the impact of diverse efficiency levels on the rent generated by the fishery, *iii*) the influence of multispecificity and catch composition on effective management and *iv*) the identification of the most sustainable fishing practices in terms of CO_2 emissions. First, the relevance of an efficiency analysis of the TBB fishery is related to the regulatory framework applied in the Adriatic Sea. Fisheries management in the GSA 17, as in most Mediterranean basins, is constituted of a variety of instruments such as effort reductions, technical measures (e.g. minimum landing sizes and mesh limitations) and seasonal or permanent area closures (Sabatella et al., 2017). In terms of activity, fishing days of the TBB fishery in the GSA 17 have decreased by 44.2% between 2010 and 2020 (STECF, 2022). Taking into account that Mediterranean fisheries are often characterized by low levels of economic efficiency (Colloca et al., 2013; Maynou, 2014; Sabatella et al., 2017), capacity reduction programmes that overlook the heterogeneity of a fleet might be ineffective, hence stressing the relevance of individual measures of vessels' efficiency (Gómez and Maynou, 2020). Investigation of the relative heterogeneity among vessels also provides crucial information concerning the existence and size of the total producer surplus, which is an important component of the economic welfare generated by a fishery (Jensen et al., 2019). Given the presence of different levels of efficiency, it is advisable to consider in advance the distributional effects deriving from effort limitations (i.e. varying levels of reduction in individual producer surplus due to differences in the cost per unit of effort among vessels) and the compensations that might be needed in order to prevent the likelihood of non-compliance by fishers (Flaaten, 2011).

Moreover, it is important to remark that regulations based on physical parameters (e.g. the gear used) ignore that vessels within the same fleet may target different species in mixed fisheries, therefore multivariate analysis of catch composition can provide valuable information for management purposes (Lewy and Vinther, 1994). Given the growing interest for an ecosystem-based approach to fisheries management (Link, 2002; Hilborn, 2011; Long et al., 2015), first included in the 2013 reform of the Common Fisheries Policy and still regarded as one of the main instruments for guaranteeing the sustainability of EU fisheries (European Commission, 2023), cluster analysis has the potential to identify patterns of resource usage that can support the definition of appropriate spatial and temporal ecosystem-based management units (Lucey and Fogarty, 2013). Additionally, it has been claimed that the results from cluster analysis of catch assemblage have a variety of practical applications, such as modelling realistic fisher behaviour, supporting scientific advice on previously overlooked species, and understanding potential changes in fishing practices in response to landing obligations (Moore et al., 2019).

In this paper we also include a quantification of the GHGs emissions generated by fishing operations (fishing and navigation) through the estimation of the CO_2 produced by the TBB vessels of Chioggia. The awareness that fishing practices contribute significantly to global GHGs emissions has increased in the last decades (Coello et al., 2015; Driscoll and Tyedmers, 2010; Cheilari et al., 2013), and innovative solutions for improved fuel efficiency are widely discussed (Parente et al., 2008; Sala et al., 2011; Fiorentini et al., 2004). This is especially relevant in the case of large-scale fisheries, which tend to be more fuel-intensive than small-scale fisheries (Cavraro et al., 2023; Suuronen et al., 2012). In the Adriatic Sea, previous studies have assessed the energy performance of the TBB fishery relative to other gears and compared the emissions intensity (expressed as CO_2 produced per quantity of landed fish) among the main target species (Russo, 2020; Sala et al., 2022). We differentiate our analysis by focusing exclusively on the TBB fleet and confronting the emissions generated by different catch profiles throughout the year 2019 within the same fishery.

To the authors' knowledge, this is the first scientific article connecting the study of technical efficiency with multivariate analysis of catch profiles in fisheries. In addition, while the catch assemblage of TBB in the GSA 17 has been previously investigated through cluster analysis (i.e. main targeted species with respect to other demersal gears operating in the Adriatic Sea) (Armelloni et al., 2021), we are not aware of studies differentiating among the catch profiles of *rapido* vessels at trip level or providing technical efficiency estimates of their fishing operations. Our work attempts to fill this gap and hence to address the concern for increased efficiency of fishing practices in the large-scale sector of the European fleet (Symes, 2014; European Commission, 2009).

More specifically, the present article addresses the two following research questions: *i*) in the case of the TBB fishery in the GSA 17, how does technical efficiency vary among fishing trips characterized by different catch profiles and *ii*) how do these trips perform in terms of CO_2 emissions? In the next section, we present the theoretical framework and the empirical approach to address the research questions. Section 4.3 describes the fishing and market data used in the analysis while the results are shown in Section 4.4. We discuss the main findings and the limitations of our approach in Section 4.5, which also concludes the paper.

4.2. Methodology

With regard to the methodological approach adopted in this paper, we proceed as follows. The first step involves the identification of the most relevant catch profiles in the *rapido* fishery through multivariate analysis of landings composition. We then estimate the technical efficiency of fishing operations by means of Stochastic Frontier Analysis (SFA) and assign an efficiency score to each trip undertaken by the TBB fleet of Chioggia. The previously defined catch profiles are therefore used to compare the performance of fishing trips characterized by different catch profiles. The latter are lastly evaluated also in terms of environmental footprint through the estimation of the CO_2 emissions per fishing trip. We now describe the methods used in the paper starting from the multivariate analysis of catch profiles.

4.2.1. Multivariate analysis of catch profiles

Concerning the classification of trips into homogeneous groups, different approaches can be found in the literature. In general, input-based methods rely on either the technical characteristics of fishing operations retrieved from logbooks (e.g. the mesh size used, the trawled area) or direct interviews with fishers. On the other hand, output-based methods assume that catch composition reflects the intentions of fishers and therefore classify fishing trips into métiers through multivariate analysis of landing profiles. Despite their respective benefits and limitations, output-based methods are most commonly used (Marchal, 2008).

In this paper we attempt to define groups of homogenous fishing trips by means of cluster analysis, a data-exploratory technique which classifies objects into different clusters based on their internal cohesion and external isolation[19] (Everitt et al., 2011). Cluster analysis is generally divided into partition and hierarchical methods, with both approaches being extensively applied to identify métiers in fisheries. In this paper we apply the k-means partition clustering method (Bastardie et al., 2010; Fall et al., 2006; Lucey and Fogarty, 2013; Williams and Ralston, 2002) to characterize clusters using the species composition of each trip[20]. The method starts by pre-setting a number of *k* clusters to be defined through an iterative process which, depending on the initial seed values, relocates objects to the group whose mean (centroid) is the nearest and the algorithm stops when no objects change group. If the number of clusters is not known *a priori*, it is necessary to calculate and compare alternative solutions with different *k* numbers of groups based on one or more criteria. These typically include *i*) the search for the "kink

[19] Even if it is not necessary for clustering, a Principal Component Analysis (PCA) can be performed in advance in order to reduce the dimensionality of a dataset by aggregating highly correlated variables into a reduced number of principal components. In the fisheries literature, an initial PCA is commonly conducted in the presence of datasets covering a high number of species (Iriondo et al., 2010; Moore et al., 2019).

[20] The variables analyzed are the catch proportions (in terms of weight) of each of the seven species considered (SOL, CTC, BOY, TGS, MTS, QSC, SJA) relative to the total landings. The remaining species are grouped together as the proportion of "other species".

in the curve" derived from the within sum of squares or *ii*) its logarithm for all cluster solutions, *iii*) the η^2 coefficient (indicating the decrease of the within sum of squares for every solution compared with the total sum of squares) and *iv*) the proportional reduction of error coefficient (indicating the decrease of the within sum of squares for cluster solution k compared with the previous solution with one *k-1* clusters) (Makles, 2012). We perform the analysis in STATA 16 using the *cluster kmeans* command and determine the appropriate number of clusters by comparing the results of the four criteria for different cluster solutions.

4.2.2. Technical efficiency and model specification

In a wide range of industries, including the fishing sector, firms can be described in terms of technical efficiency by looking at their generated output given a set of resource inputs. The difference between the observed and the potential production measures the level of technical efficiency of a firm, with inefficient units operating below the frontier. Measurement of technical efficiency will thus depend on the estimation of a production function for a specific industry, which is usually based on either Data Envelopment Analysis (DEA) or SFA. In the former approach the frontier is identified using linear programming techniques, while econometric estimation is performed in the latter. Both DEA (Gómez and Maynou, 2020; Guyader and Daurès, 2005; Reid et al., 2003; Sangün et al., 2018; Vázquez-Rowe and Tyedmers, 2013) and SFA (Dağtekin et al., 2021; Greenville et al., 2006; Pascoe et al., 2001; Solís et al., 2013; Van Nguyen et al., 2019) have been widely applied in the fisheries literature. Even if both approaches have their advantages and disadvantages (Pascoe and Tingley, 2007), the present work makes use of SFA due to its ability to take into account statistical noise given the stochastic nature of the production process in the fishery, as opposed to the deterministic nature of DEA (Herrero and Pascoe, 2003).

SFA generalizes the classical production function approach, which assumes that there are no differences in the efficient use of inputs among units, by incorporating a non-symmetric two-component error made of a regular idiosyncratic disturbance and a one-sided non-negative component representing technical inefficiency and preventing the achievement of the maximum feasible output (Nguyen et al., 2022). A stochastic frontier production function can be defined as follows:

$$y_{it} = f(x_{it}; \alpha) + v_{it} - u_{it} \tag{1}$$

where y_{it} is the (logged) output of producer i in the tth time period, $f(x_{it}; \alpha)$ is the production technology, x_{it} is the vector of (logged) input quantities, α is the vector of associated unknown parameters, v_{it} denotes stochastic noise and u_{it} represents technical inefficiency. The random errors are assumed to be independently and identically distributed following a normal distribution $N(0, \sigma_v^2)$ while technical efficiency is non-negative, independently and identically distributed with variance σ_u^2. If $u_{it} = 0$, producer i at time t lies on the stochastic frontier and is therefore fully efficient. On the contrary, a value greater than zero indicates a production below the frontier.

Different distributional assumptions can be made for the inefficiency term u_{it}, with half-normal (Jondrow et al., 1982), exponential (Meeusen and van der Broeck, 1977), truncated normal (Aigner et al., 1977) and gamma (Greene, 1990) distributions being widely used in the literature. Inefficiency can also be modelled as a function of exogenous variables (Battese and Coelli, 1995).

Panel data models for the estimation of technical efficiency can be classified into four groups depending on the assumptions made on the temporal behavior of inefficiency: time-invariant and individual specific, individual specific but time-varying, separated from unobserved individual effects, composed of both a persistent and a time-varying component and separated from unobservable individual effects (Kumbhakar et al., 2015). Given our interest in estimating the efficiency of fishing trips and comparing the scores among catch profiles (rather than vessels), in this paper we apply the model by Kumbhakar and Heshmati (1995), which belongs to the fourth group of models. This allows us to isolate the effect of persistent inefficiency, whose magnitude can be relevant in short panels (only one year in our case) because it reflects the effect of inputs like management (Mundlak, 1961)[21]. While most efficiency studies in fisheries rely on the model by Battese and Coelli (1995) (Pascoe et al., 2003)- which does not distinguish between persistent and time-varying inefficiency (Kumbhakar et al., 2015)- the panel data model by Kumbhakar and Heshmati (1995) model allows for this distinction, therefore it can isolate the effectiveness of one catch profile over others. Technical efficiency is here further decomposed as

$$u_{it} = u_i + \tau_{it} \tag{2}$$

where u_i is the persistent component (vessel-specific and time-invariant) and τ_{it} is the residual component (vessel-specific and time-variant).

The model, which is presented in a random effects framework due to the presence of a fixed input (engine power) and the nature of the data (a rotating panel with some vessels entering and exiting the fishery throughout the year), is estimated following a multistep procedure (Kumbhakar and Heshmati, 1995)[22]. In particular, taking a translog function as the production technology, the model is rewritten as:

$$\ln (Y_{it}) = \alpha_0^* + \gamma' X_{it} + u_i^* + \omega_{it}, \tag{3}$$

$$\alpha_0^* = \alpha_0 + E(u_i) + E(\tau_{it}), \tag{4}$$

[21] In the case of a fishery, this could be approximated by skipper skill or experience, which have been indeed included as control variables in previous studies of technical efficiency (Pascoe and Coglan, 2002; Del Valle et al., 2003).

[22] A functional form describing the fishing technology (the relationship between inputs and output) has to be chosen for estimation. This can take the form of a Cobb-Douglas, constant elasticity of substitution or translog function (Squires and Kirkley, 1999). Here we specify the production function as a translog due of its flexibility and because it does not impose constraints on the elasticities of substitution between inputs (García Del Hoyo et al., 2004; Herrero and Pascoe, 2003; Squires, 1987).

$$u_i^* = u_i - E(u_i), \tag{5}$$

$$\omega_{it}^* = v_{it} + \tau_{it} - E(\tau_{it}) \tag{6}$$

where the X_{it} vector includes the linear, quadratic and cross-product terms of the (logged) explanatory variables and γ is the corresponding parameter vector. First, the production function parameters γ are estimated using Generalized Least Squares (GLS). The residuals $e_{it} = \ln(Y_{it}) - \hat{\gamma}' X_{it}$ are then used to estimate persistent technical efficiency from:

$$\hat{u}_i = \bar{e}_i - \max_i\{\bar{e}_i\} \tag{7}$$

where $\bar{e}_i$ is the mean of e_i of producer (i.e. vessel) i over the time period. Assuming that the residual component of efficiency is truncated at zero as the random errors $N(0, \sigma_\tau^2)$, Maximum Likelihood is used to estimate the intercept α_0, σ_τ^2 and σ_v^2. Lastly, τ_{it} for each observation is estimated based on the JLMS technique (Jondrow et al., 1982):

$$\hat{\tau}_{it} = \frac{\hat{\lambda}\hat{\sigma}}{(1+\hat{\lambda}^2)}\left[\frac{\hat{\lambda}\omega_{it}}{\hat{\sigma}} - \frac{\phi(\frac{\hat{\lambda}\omega_{it}}{\hat{\sigma}})}{\Phi(-\frac{\hat{\lambda}\omega_{it}}{\hat{\sigma}})}\right] \tag{8}$$

where $\lambda = \sigma_\tau/\sigma_v$, $\sigma = \sigma_\tau^2 + \sigma_v^2$, $\Phi(\cdot)$ is the cumulative distribution function of the standard normal variable and $\phi(\cdot)$ is the standard normal density function. The respective scores for persistent (PTE), residual (RTE) and overall (OTE) technical efficiency are finally computed as: $\mathrm{PTE_i} = \exp(\hat{u}_i)$, $\mathrm{RTE_{it}} = \exp(\hat{\tau}_{it})$ and $\mathrm{OTE_{it}} = \exp(\hat{u}_i + \hat{\tau}_{it})$[23]. Regarding the functional specification relating inputs and output, the estimated function is given by:

$$\begin{aligned} \ln V_{it} = {} & \alpha_0 + \alpha_{NT}\ln NT_{it} + \alpha_{FT}\ln FT_{it} + \alpha_{KW}\ln kW_i + \alpha_{NTNT}(\ln NT_{it})^2 + \alpha_{FTFT}(\ln FT_{it})^2 \\ & + \alpha_{KWKW}(\ln kW_i)^2 + \alpha_{NTFT}(\ln NT_{it}\cdot \ln FT_{it}) + \alpha_{NTKW}(\ln NT_{it}\cdot \ln kW_i) \\ & + \alpha_{FTKW}(\ln FT_{it}\cdot \ln kW_i) + \alpha_4 D_t + v_{it} - u_{it} \end{aligned} \tag{9}$$

where V_{it} is the trip output measured as catch value, NT_{it} is the navigation time in hours, FT_{it} is the fishing time in hours, kW_i denotes the engine power measured in kilowatts and D_t is a monthly dummy. Concerning the selection of variables, catch value- instead of landings- is often preferred to denote the output in efficiency studies of fisheries. Even if this implies that the efficiency scores may represent a combination of technical and allocative

[23] The procedure, and the corresponding STATA code to replicate the analysis, is described in detail by Kumbhakar et al. (2015 p.272).

efficiency given that prices are not fixed, catch value as an output is likely to be more consistent with the behavioral characteristics of the vessel crew (Pascoe and Coglan, 2002). As for the input factors, these incorporate fishing effort and fish stock. While the latter is outside the control of the fisher, the former usually comprises a fixed component reflecting fishing power (such as vessel tonnage, length or engine power) and a variable component reflecting the time at sea (Andersen, 2002). We therefore use engine power as a fixed input[24] and the hours at sea[25] for each fishing trip as a variable input. Having AIS data that allow us to distinguish between navigation time and fishing time, we attempt to more accurately describe fishing operations by dividing the time at sea in these two parts. Lastly, a dummy approach is adopted to describe monthly stock fluctuations (Coglan et al., 1999; Fousekis and Klonaris, 2003; Pascoe and Robinson, 1998; Yang et al., 2017).

4.2.3. CO_2 emissions

With regard to the estimation of CO_2 emissions generated by TBB, these depend on the physical characteristics of the vessel and the time spent at sea during the fishing trip. In particular, based on the engine power of vessels and their respective fishing/navigating time, we are able to compute fuel consumption for fishing FCF_{it} and navigation FCN_{it} of each trip following the equation by Prado (1990):

$$FCF_{it} = a \cdot kW_i \cdot \frac{S_f}{d} \cdot FT_{it} \cdot 0.001, \tag{10}$$

$$FCN_{it} = a \cdot kW_i \cdot \frac{S_n}{d} \cdot FT_{it} \cdot 0.001 \tag{11}$$

where a is the average coefficient set at 0.75 (Prado, 1990), S is the specific fuel consumption (set at 188 g/kW*h for fishing and 150.4 g/kW*h for navigation) (Lee et al., 2018) and d denotes fuel density (0.86 kg/l). Finally, fuel consumption is used to calculate the carbon footprint of a fishing trip using the basic method Tier 1 (Park et al., 2015; IPCC, 2008) :

$$CO_{2_{it}} = (FCF_{it} + FCN_{it}) \cdot EF \tag{12}$$

where the emission factor EF is set at 2.86 kg CO_2 per liter of fuel consumed (Parker et al., 2018).

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[24] Choosing engine power (rather than length) follows the management measures for demersal fish stocks in Northern Adriatic, which aim to reduce fishing pressure by decreasing the total kilowatts and fishing days in the fishery. Nevertheless, the two inputs highly correlated (p 0.65, 1% significance).

[25] The use of navigation and fishing hours can be problematic in the estimation process since the variable may be endogenous-the so-called "simultaneity bias" (i.e. fishers spend more time at sea when the trips are more profitable). However, the selection of inputs based on predicted profits will be subject to mistakes that are uncorrelated with the error components in the production function due to the stochastic nature of the output (i.e. unpredictable weather and environmental conditions, the "luck" component), thus resulting in consistent parameter estimates (Kirkley et al., 1998; Pascoe and Coglan, 2002).

4.3. Data description

4.3.1. Fishing activity

Raw Automatic Identification System (AIS) data are provided by the Italian Coast Guard (ITC and Traffic Monitoring Department – Rome). The dataset contains several information [Maritime Mobile Service Identity (MMSI), speed, time, and geographical coordinates] on 2,404 fishing trips undertaken by 31 *rapido* trawls (TBB) from the fishery based in Chioggia port in the year 2019. These vessels represent respectively 86.1% of the Veneto region and 34.1% of the Italian TBB fleet (NISEA, 2022b). Concerning the individual characteristics of the vessels, the International Radio Call Sign (IRCS), ship name, and MMSI number are utilized to identify each *rapido*. The vessel IRCS and name, included in the AIS data, are subsequently matched with the EU Fleet Register, which contains data on the physical features of the vessels, such as engine power, length overall (LOA) and year of construction. In some case, such as misspelled IRCS or ship's name, the vessel identification is performed by using the Marine Traffic website. In addition, the speed frequency distribution of each vessel, as well as the catch profiles, are used to detect the principal gear and/or its possible switch.

The analysis of AIS data, relative to the TBB fleet of Chioggia (GSA 17), is performed following the procedure reported in Russo et al. (2020; 2021). Briefly, the dataset is processed by using PostgreSQL, an opensource object-relational database. First, all duplicate records and erroneous positions are removed, then the trajectories of each TBB are reconstructed by linearly interpolating the AIS data from the departure to the return port. A trajectory is defined as a sequence of segments with different activity (in port, exiting from port, entering to port, fishing, and navigation) defined on the base of the vessel position and the typical fishing speed range of TBB (4-7 knots) (Russo et al., 2020). Then, the daily quantity of landings, provided by the Chioggia Fish Market, is associated to each fishing trip through the MMSI.

4.3.2. Market data

With regard to the construction of the output variable, which indicates the value of landings, we make use of the daily prices from Chioggia Fish Wholesale Market. We chose to request the price time series for the five most relevant species caught by the TBB fleet in 2019 in the GSA 17, covering 76.2% of its total landed value according to the Economic and Transversal data by STECF (2022). These are: common sole (*Solea solea*, SOL), common cuttlefish *(Sepia officinalis*, CTC), purple dye murex (*Bolinus brandaris*, BOY), caramote prawn (*Melicertus kerathurus,* TGS) and spottail mantis *shrimp* (*Squilla mantis*, MTS). In addition, based on previous literature that highlights the importance of these two species for the Chioggia *rapido* fishery (Pranovi et al., 2001), we also requested the daily prices of queen scallop (*Aequipecten opercularis*, QSC) and great Mediterranean scallop (*Pecten jacobaeus*, SJA) and included them in the analysis. Taking into account the significance of the seven species under consideration for this fishery[26], the output variable V_{it} effectively approximates the total revenues generated by fishing trips. Summary statistics of the variables considered in the study are presented in Table 1. For a more detailed description, Table A1 reports the summary statistics divided by month.

Table 1 - Summary statistics for sample vessels. Note: weight and value refer to the seven species under analysis.

Variable	Median	Mean	Std.Dev.
Engine power (kW)	441.00	433.17	121.00
Fishing time (hours)	17.55	19.48	10.36
Navigation time (hours)	4.91	8.62	28.52
Fuel fishing (liters)	1179.84	1458.38	963.50
Fuel navigation (liters)	281.16	496.85	1933.34
Landings weight (kg)	341.98	423.53	357.97
Landings value (€)	2718.22	3273.53	2721.71
CO_2 (kg)	4493.62	5591.96	6188.08
N= 2404 observations			

4.4. Results

4.4.1. Cluster analysis

Table 2 - Catch profiles composition and frequency based on cluster analysis. The species under consideration are common sole (SOL), common cuttlefish (CTC), purple dye murex (BOY), caramote prawn (TGS), spottail mantis shrimp (MTS), queen scallop (QSC) and great Mediterranean scallop (SJA).

	Proportion of landings							
	SOL	CTC	BOY	TGS	MTS	QSC	SJA	Other
Cluster 1	0.36	0.35	0.02	0.02	0.03	0.03	0.07	0.13
Cluster 2	0.08	0.04	0.02	0.00	0.01	0.75	0.09	0.01
Cluster 3	0.66	0.07	0.05	0.01	0.06	0.01	0.05	0.10
Cluster 4	0.34	0.05	0.14	0.01	0.06	0.04	0.26	0.10
Cluster 5	0.02	0.10	0.03	0.02	0.07	0.00	0.01	0.75

	Monthly observations										
	J	F	M	A	M	J	J	S	O	N	D
Cluster 1	161	146	89	41	1	1	0	7	44	50	70
Cluster 2	18	31	26	43	39	44	41	29	30	22	20
Cluster 3	33	55	54	87	136	96	83	79	91	104	92
Cluster 4	12	8	47	53	67	68	53	41	33	14	14
Cluster 5	11	14	7	9	10	8	7	18	19	13	15

[26] In the year 2019, these species showed the following relevance over the total value landed by TBB in the GSA 17: SOL 42.0%, CTC 11.9%, BOY 10.1%, MTS 7.0%, TGS 5.1% and SJA 4.2%. Data for QSC is aggregated with other scallop species (STECF, 2022).

Since k-means is a stochastic method, the cluster analysis is repeated with different initial seed values in order to test the robustness of the results. Through graphical inspection of the four criteria described in Makles (2012), we find the most appropriate number to be five clusters. These are reported in Table 2, which shows the average proportion of each of the seven species (SOL, CTC, BOY, TGS, MTS, QSC, SJA) over total landings per catch profile. The remaining species are labelled as "other". The table also provides an indication of the number of observations belonging to the five clusters during each month of the year[27]. Conditional formatting is used to ease the interpretation of the table and to provide a clear indication of both the most relevant species per catch profile and their seasonality. In particular, Cluster 1 is characterized by the prevalence of common sole and common cuttlefish landings and it's the most frequent catch profile over the Winter season (377 observations from December to February). Fishing trips belonging to Cluster 2 almost exclusively target queen scallop and, despite their low frequency (343 observations in 2019), they tend to be quite equally distributed during the year. Cluster 3 is characterized by the highest incidence of sole over total landings and it's the most frequent catch profile of the sample (910 fishing trips), with peaks in May and November. Other than the presence of sole, fishing trips from Cluster 4 also exhibit a proportion of purple dye murex and great Mediterranean scallop higher than the average and they are concentrated between March and October. Lastly, all the observations belonging to Cluster 5 (131 observations) are dropped from the analysis due to the high incidence of the species labelled as "other" (75% of landings), which would compromise the reliability of the efficiency estimates because the revenues from fishing operations would be only partially reflected in the value of landings.

4.4.2. *Technical efficiency and CO_2 estimation*

Table 3 - Monthly variations in efficiency scores and emissions per fishing trip. The results are differentiated by catch profile (Clusters 1-4).

Month			**J**	**F**	**M**	**A**	**M**	**J**	**J**	**S**	**O**	**N**	**D**
Cluster 1	N		161	146	89	41	1	1	0	7	44	50	70
	Efficiency	*Mean*	0.67	0.67	0.67	0.62	0.49	0.17	.	0.69	0.66	0.67	0.65
		Median	0.67	0.70	0.70	0.66	0.49	0.17	.	0.66	0.69	0.70	0.66
		Std.Dev.	0.10	0.12	0.14	0.12	.	.	.	0.10	0.11	0.11	0.12
	CO_2 Kg	*Mean*	8224	7824	7201	11800	1310	2058	.	6594	6749	6084	7702
		Median	8256	7488	7015	10080	1310	2058	.	6584	6416	5874	7588
		Std.Dev.	7009	4372	3758	13150	.	.	.	1881	2452	2539	3617
Cluster 2	N		18	31	26	43	39	44	41	29	30	22	20
	Efficiency	*Mean*	0.70	0.64	0.68	0.69	0.76	0.75	0.65	0.58	0.62	0.61	0.62
		Median	0.72	0.64	0.69	0.68	0.81	0.77	0.69	0.55	0.60	0.64	0.70
		Std.Dev.	0.13	0.16	0.14	0.13	0.13	0.09	0.17	0.12	0.13	0.13	0.17

[27] Each year a temporary fishery closure in the Summer season is established. In 2019, the ban (in ital. "*fermo pesca*") took place from July 29th to September 6th in the Veneto region.

	CO_2 Kg	*Mean*	2450	2555	2975	3162	4776	3283	2947	3472	2995	2639	2757
		Median	2421	2605	2549	2714	2899	2718	2548	2787	2602	2433	2648
		Std.Dev.	521	586	1868	1869	7909	2112	1814	2141	946	972	729
Cluster 3	N		33	55	54	87	136	96	83	79	91	104	92
	Efficiency	*Mean*	0.62	0.64	0.65	0.66	0.65	0.65	0.68	0.70	0.69	0.69	0.70
		Median	0.63	0.65	0.69	0.66	0.66	0.65	0.67	0.70	0.70	0.70	0.72
		Std.Dev.	0.12	0.11	0.16	0.11	0.13	0.12	0.10	0.11	0.12	0.13	0.12
	CO_2 Kg	*Mean*	4678	4995	3565	5213	6498	4806	4679	3878	5698	4306	5342
		Median	2885	3677	3304	4465	3543	3691	3910	3534	5167	3602	5117
		Std.Dev.	3959	3581	1857	2863	19334	2844	3144	2078	3194	2449	2834
Cluster 4	N		12	8	47	53	67	68	53	41	33	14	14
	Efficiency	*Mean*	0.51	0.47	0.61	0.62	0.56	0.59	0.62	0.61	0.58	0.40	0.47
		Median	0.55	0.47	0.64	0.63	0.56	0.59	0.65	0.65	0.62	0.44	0.56
		Std.Dev.	0.15	0.22	0.13	0.12	0.14	0.15	0.13	0.10	0.18	0.16	0.28
	CO_2 Kg	*Mean*	5238	4719	4755	5340	5643	5261	5305	5077	6446	4396	5295
		Median	3929	4435	3923	4332	4695	4672	4524	4895	5895	4204	4951
		Std.Dev.	2442	2094	2062	2698	3202	2373	2599	1480	2480	1115	1954

Concerning the analysis of technical efficiency (the estimated production function parameters can be found in Table A2), Table 3 shows the efficiency scores and the CO_2 emissions associated with the four catch profiles (Cluster 1 to 4) during each month of the year. Conditional formatting is used to highlight the relative frequency of observations belonging to one group and to compare the median efficiency scores and emissions among clusters. If read from the top to the bottom, Table 3 allows to confront the four clusters within the same month, while through horizontal reading we can follow the performance of each cluster during the year. First, it emerges that it is important to inspect the efficiency scores and the emissions at the monthly level because both of them tend to vary consistently across the year. For instance, Cluster 2 is characterized by high efficiency between May and June, but it is relatively underperforming in the Autumn months. Similarly, the number of observations denotes whether a catch profile tends to be stable during the year or not. Cluster 1 is indeed the most recurring strategy in the Winter months, while it almost disappears between May and September.

In terms of efficiency, the highest scores are reached by Cluster 2 in May (mean=0.76, median=0.81) and June (mean=0.75, median=0.77). Nevertheless, Cluster 2 is not the most frequent catch profile in these two months (83 observations), but is preceded by Cluster 3 (232 observations) and 4 (135 observations) despite their lower efficiency scores. Vertical reading of Table 3 thus helps us understand if the fishery is operating optimally or, on the contrary, there are vessels that favor one catch profile over the others even if it does not assure the highest value of landings given the set of inputs employed. For instance, in February the vast majority of fishing trips belong to Cluster 1 (146 observations), which is also the catch profile with highest scores (mean=0.67, median=0.70), meaning that vessels targeting together sole and cuttlefish are the most efficient. Likewise, in September Cluster 3 appears to be both the most efficient catch profile (mean=0.70, median=0.70) and the most preferred strategy among fishermen (79 observations). It is interesting to observe that in some periods of the year fishers tend to exhibit mostly one (i.e. in January) or two (i.e. in December) catch profiles, while in others the probability of belonging to one cluster is more equally distributed among the four. This is the case of April, when all the clusters are characterized by at least 40 observations and none of them has an average or median efficiency score lower than 0.62 or greater than 0.69. In other words, *rapido* vessels could either choose to target almost exclusively queen scallop (Cluster 2) or prioritize sole landings (Cluster 3) with no major differences in terms of efficiency. However, the two strategies are definitely not comparable from an environmental point of view, with the median value of CO_2 emissions from Cluster 2 being only 61% of Cluster 3. The result can be explained by the fact that, although in April fishing trips belonging to Cluster 3 are characterized by a higher duration and fuel combustion (Table A3), the value of landings is enough to compensate for the additional input usage. Overall, it can be argued that both Clusters 1, 2 and 3 tend to outperform Cluster 4 in terms of efficiency. In particular, when considering only median values, we estimate the most efficient catch profile to be Cluster 1 in two months (February, March), Cluster 2 in five (January, April, May, June, July) and Cluster 3 in four months (September, October, November, December). TBB targeting together sole, purple dye murex and great Mediterranean scallop (Cluster 4) are relatively frequent in May (67 observations) and June (68 observations) but they could substantially be more efficient by changing the composition of their landings in favor of sole or queen scallop.

When considering the emissions generated by fishing trips, it is clear that there are significant variations among catch profiles. In addition, we observe that the energy performance of a cluster can also change throughout the year, meaning that a fishing strategy that is sustainable in one period might become excessively polluting in the following months. In general, we see that fishing trips from Cluster 2 are continuously marked by lower levels of CO_2 emissions, so it can be argued that *rapido* vessels targeting mainly queen scallop are the most sustainable during each of the months under consideration (with only two observations, Cluster 1 is not considered a feasible alternative between May and June). The opposite extreme is represented by fishing trips from Cluster 1, which generate severe levels of emissions during most of the year, reaching the highest peaks in April (mean=11800 Kg, median=10080 Kg) and January (mean=8224 Kg, median=8256 Kg). Cluster 3 and 4 show an intermediate energy performance. Specifically, it is worth noting that catch profiles with major sole incidence (Cluster 3) are characterized by great variability both across the year (January median=2885 Kg, October median=5167 Kg) and intramonth, as indicated by the discrepancy between mean and median values and high standard deviations. On the other hand, fishing trips targeting together sole, purple dye murex and great Mediterranean scallop (Cluster 4) tend to be relatively more stable, especially in Spring/Summer, when they are more frequent (May median=4695 Kg, June median=4672 Kg). We also stress the fact that the carbon footprint of each catch profile is a product of both fishing/navigation time and engine power. In this regard, fishing trips from Cluster 2 are not only characterized by a shorter time at sea (19 hours at sea on average) but they are also preferred by TBB with lower engine power (367 kW on average), hence explaining the reduced CO_2 emissions of this catch profile compared to the others[28]. Lastly, the validity of the results is confirmed by examining the ratio of CO2 emissions to the total value of landings from the seven species being studied. Once more, Cluster 2 fishing trips emerge as the most efficient, displaying a median emission intensity of 0.62 kg of CO2 per euro earned from catch. This is followed by Cluster 3 (1.67 kg/euro), Cluster 1 (1.82 kg/euro), and Cluster 4 (2.34 kg/euro).

4.5. Discussion and conclusions

Our analysis shows that linking multivariate analysis of catch profiles to SFA can be an effective tool to understand the dynamics taking place in the fishery at the vessel level, hence providing both managers, fishers and policy-makers practical indications to improve the efficiency of the sector. Including an inventory of GHGs emissions in the analysis also allows to compare the economic performance and the environmental sustainability of the fishery, and therefore to identify the periods of the year or catch profiles where both dimensions coexist. From a management perspective, our approach highlights that some heterogeneity does exist within the *rapido* fishery of Chioggia. In particular, the differences are related to the fisher's behaviour, probably depending on handed down patterns of fishing performance, the movement of the main target species (e.g. seasonal migrations), regulatory limitations and the characteristics of the fishing grounds (e.g. type of sediment, bathymetry). This aspect could be related to the partial overlapping of fishing grounds with other gears, especially bottom otter trawls, which can compete for the same areas and resources (Russo et al., 2020). Such information should be carefully considered when planning future capacity reduction programmes, because the effectiveness of such measures heavily depends on the efficiency of the units involved (Pascoe and Coglan, 2000)[29]. Similarly, further reductions in fishing days as prescribed in the last EU regulations for the GSA 17 (-3% between 2022 and 2023) (Council of the EU, 2022; 2023) may not reach the target of reducing the pressure on all fish stocks if fishers are able to switch among catch profiles (i.e. changing the target species). Our analysis shows indeed that TBB- especially the ones with more powerful engines- do not necessarily belong to the same cluster during the whole year and they may even report landings with different composition in the same month. An exception is represented by a few

[28] The highest levels of emissions are associated with Cluster 1, whose catch profile is targeted by powerful *rapido* vessels (478 kW on average) during fishing trips with long time at sea (36 hours). Cluster 3 (416 kW, 26 hours) and 4 (478 kW, 25 hours) lie in between the two.
[29] In the period 2014-2020, 1,877,970 € have been allocated to the TBB segment of the Italian fleet under Article 34 of the European Maritime and Fisheries Fund for permanent cessation of fishing activities (Gambino et al., 2022).

small/medium sized vessels targeting mostly queen scallop (Cluster 2), which show less inter-cluster mobility (Figure A1)[30]. In general, heterogeneity emerges at two levels: firstly, in the differences in technical efficiency among vessels. Secondly, there is heterogeneity in terms of different strategies coexisting throughout the year. Heterogeneity can also be related to differences in physical characteristics of the vessels (information retrieved from the Fleet Register), with larger TBB being more efficient in specific seasons and smaller TBB in others. For instance, a two-sample t test indicates that vessels with engine power above the average (433.17 kW) have higher scores in February ($Pr(T < t) = 0.0143$), while boats with engine power below the average perform better in July ($Pr(T > t) = 0.0126$).

Depending on the priority weightings placed by management institutions (economic efficiency, carbon neutrality, stock preservation), this type of analysis can support the selection of the most appropriate temporal units for future regulations involving a reduction in fishing days. To ensure that these have no impact on market supply and do not result in the closure of established commercial circuits, it is essential to consider both the distribution of fishing time limitations throughout the year in addition to the fishing time reduction itself (Sánchez Lizaso et al., 2020). On the other hand, even if the introduction of quotas has been traditionally rejected in the Mediterranean Sea due to the multispecific nature of most fisheries (Carpi et al., 2017; Mulazzani et al., 2018), it is reasonable to presume that setting a total allowable catch (TAC) for sole in the Autumn/Winter season would prevent the fall in prices that occurs in November (6.35 €/kg) and December (6.89 €/kg)[31], especially considering that sole represents about 50% of landings in these months.

Two policy options emerge at this juncture. Firstly, the measure of vessel withdrawals, removing from the, fleet less efficient boats and/or those disproportionally contributing to GHGs emissions. Although the effectiveness of decommissioning schemes has been historically criticized, especially in Italy (Spagnolo, 2010), efficiency analysis could indeed serve as a useful tool to select the most appropriate units to involve (Kirkley and Squires, 2003), in particular in those contexts where fishing effort is above sustainable levels. Secondly, engaging fishers to reorganize and channel production, changing fishing pattern of individual vessels and selecting the more efficient combination of strategy and period. In this regard, an important role could be played by Producer Organizations to engage all relevant stakeholders at the local level (European Commission, 2023b), with the Veneto region already having a positive example represented by Territorial Use Rights for clams management (Spagnolo, 2007; Lucchetti et al., 2022). Despite the organizational effort required, the latter option appears more

[30] With regard to the influence of the year of construction of the *rapido*, graphical inspection of Figure A1 suggests that older vessels are less able to move among clusters. This is confirmed by the fact that five out of the first six boxes at the top identify TBB with an age above 28 years (median value in the sample). Engine power is indeed negatively correlated with vessel age (p -0.52, 1% significance).
[31] The average 2019 price is 8.98 €/kg, with peaks in August (12.24 €/kg), March (10.64 €/kg) and July (10.31 €/kg).

feasible, especially considering the socio-economic challenges faced by the industry (Sabatella et al. 2020). Nevertheless, efficiency analysis can also assume a crucial role with regard to the pressing issue of technological modernization of European fleets, which has been recently raised by the Commission (2023a), facilitating the identification of vessels with poor emissions performance.

We stress the fact that our analysis has some limitations. First, we consider data referring to a single year, so our findings do not take into account possible stock fluctuations occurring over the long run, which may imply a change in the behaviour of fishers with regard to the targeted species. Furthermore, the results related to the analysis of carbon emissions rely on the assumed functional form explaining fuel consumption and the specific parameter values used, hence deserving further investigation and sensitivity analysis. In addition, we recognise that the results from efficiency analysis are dependent on the methodology used, meaning that through the application of DEA (instead of SFA) (Pascoe and Tingley, 2007), or the inclusion of different variables describing the fishing technology- for instance through economic (e.g. capital value) rather than physical (e.g. engine power) inputs (Pascoe et al., 2003)-, deviations in the efficiency estimates might occur. Nevertheless, it is important to remark that the use of the model by Kumbhakar and Heshmati (1995) represents an original contribution in the field of fisheries economics, since most of the efficiency studies are rather based on the application of the model by Battese and Coelli (1995) (Pascoe et al., 2003), which does not distinguish between persistent and time-varying inefficiency (Kumbhakar et al., 2015), and therefore is not able to isolate the effectiveness of one catch profile over the others. Lastly, we recognise that this work considers solely the revenues from the most relevant species, therefore the availability of price series for all the landed fish in Chioggia market could possibly alter the results from SFA due to the inclusion of potential additional revenues from non-target and incidentally captured species.

In conclusion, our study shows that there is no catch profile of the TBB fishery in Chioggia that ensures higher efficiency estimates throughout the year. While these depend on the month under consideration, we also find that, to maximize the value of the fishery, landings composed mostly of one (i.e. sole or queen scallop) or two (i.e. sole and cuttlefish) species should generally be preferred over more mixed catch profiles (i.e. sole, purple dye murex and great Mediterranean scallop). On the other hand, in terms of CO_2 emissions it emerges that fishing trips targeting queen scallop are constantly more sustainable, due to the lower time at sea and engine power of the vessels, hence resulting in reduced fuel consumption. This is mainly correlated with the distribution of queen scallop, which- compared to other target species- is located closer to the Chioggia port (Russo, 2020). This is extremely relevant when considering the EU objective of reducing GHGs emissions and the environmental footprint from fishing and aquaculture to mitigate the impacts of climate change (European Commission, 2023). However, we remark that a holistic approach to sustainable fisheries management should not consider solely GHGs emissions but other aspects, such as the exploitation status of the stock and economic profitability.

We ultimately stress that this interdisciplinary approach, combining for the first time two methodologies that are normally applied separately in marine science, has the potential to support management and policy-making also in other contexts characterised by multispecies fisheries and heterogeneous fleets. In this regard, the empirical strategy could be further enriched through the inclusion of alternative techniques both in the multivariate analysis of catch profiles (e.g. hierarchical cluster methods) and efficiency estimation (e.g. multi-output stochastic production frontiers and DEA). Incorporating spatial information describing the distribution of the areas swept by vessels during the trip is also a promising possibility for future research, especially in the context of the economic consequences related to the implementation of new protected/ fisheries restricted areas.

4.6. Appendix

Table A1 - Monthly summary statistics for sample vessels. Note: weight and value refer to the seven species under analysis.

Variable	January (*235 obs*)			February (*254 obs*)			March (*223 obs*)			April (*233 obs*)		
	m	mdn	sd	m	mdn	sd	m	mdn	sd	m	mdn	sd
Fishing time (hours)	24.0	27.9	11.6	22.6	21.8	11.8	19.3	16.1	10.4	20.6	17.5	11.3
Navigation time (hours)	10.9	7.1	28.0	9.1	6.1	13.8	6.7	4.8	7.1	9.3	4.9	29.1
Fuel fishing (liters)	1838.9	1902.4	1137.9	1690.7	1463.7	1113.7	1475.3	1099.2	979.6	1553.6	1240.9	1029.1
Fuel navigation (liters)	634.2	416.6	1861.0	518.6	362.6	892.5	390.8	267.2	376.3	555.5	260.5	2074.2
Landings weight (kg)	590.7	523.5	374.1	458.2	421.6	310.3	365.4	317.2	263.0	433.9	328.6	589.2
Landings value (€)	4495.3	4034.7	2816.9	3670.2	3396.3	2318.5	3315.3	2796.4	2508.6	3551.7	2671.3	4843.8
CO_2 (kg)	7073.1	6785.6	6339.3	6318.6	5434.4	4230.9	5336.9	4142.2	3331.8	6032.0	4482.8	6630.7
Variable	**May (*253 obs*)**			**June (*217 obs*)**			**July (*184 obs*)**			**September (*174 obs*)**		
	m	mdn	sd	m	mdn	sd	m	mdn	sd	m	mdn	sd
Fishing time (hours)	15.1	13.4	8.0	17.7	14.4	9.7	16.8	14.5	8.3	15.9	16.6	7.3
Navigation time (hours)	16.0	5.0	74.9	5.8	4.4	7.4	6.6	4.2	9.9	6.9	4.3	7.7
Fuel fishing (liters)	1120.6	949.7	739.7	1302.3	1041.2	843.1	1226.4	1053.0	809.7	1164.4	1119.0	691.7
Fuel navigation (liters)	965.4	294.1	5128.1	313.5	240.5	324.1	354.8	215.4	506.8	386.2	273.7	459.0
Landings weight (kg)	345.5	273.3	310.4	323.8	253.0	270.7	311.1	256.8	253.6	355.9	306.4	227.6
Landings value (€)	2706.4	2170.8	2107.6	2345.5	1928.9	1810.9	2465.3	2182.8	1582.0	2746.6	2465.4	1653.0
CO_2 (kg)	5966.0	3650.9	14666.3	4621.4	3669.9	2673.8	4522.3	3716.3	2831.6	4434.9	4191.9	2326.7
Variable	**October (*217 obs*)**			**November (*203 obs*)**			**December (*211 obs*)**					
	m	mdn	sd	m	mdn	sd	m	mdn	sd			
Fishing time (hours)	21.4	19.1	10.3	17.5	17.2	7.6	22.1	19.6	10.9			
Navigation time (hours)	8.1	5.5	8.5	5.6	3.9	6.9	7.4	5.4	8.7			
Fuel fishing (liters)	1543.0	1405.0	936.3	1309.0	1188.3	773.7	1698.6	1535.5	1031.7			
Fuel navigation (liters)	458.3	318.1	494.8	306.1	220.6	310.6	430.2	322.2	486.2			
Landings weight (kg)	417.7	351.3	378.4	493.2	454.3	285.1	534.6	492.3	369.3			
Landings value (€)	3382.1	2908.7	3024.3	3098.3	2918.2	1742.1	3914.5	3572.1	2632.2			
CO_2 (kg)	5723.7	5480.1	2849.1	4619.1	3979.1	2445.4	6088.4	5532.8	3562.1			

Table A2 - Random effects GLS regression results.

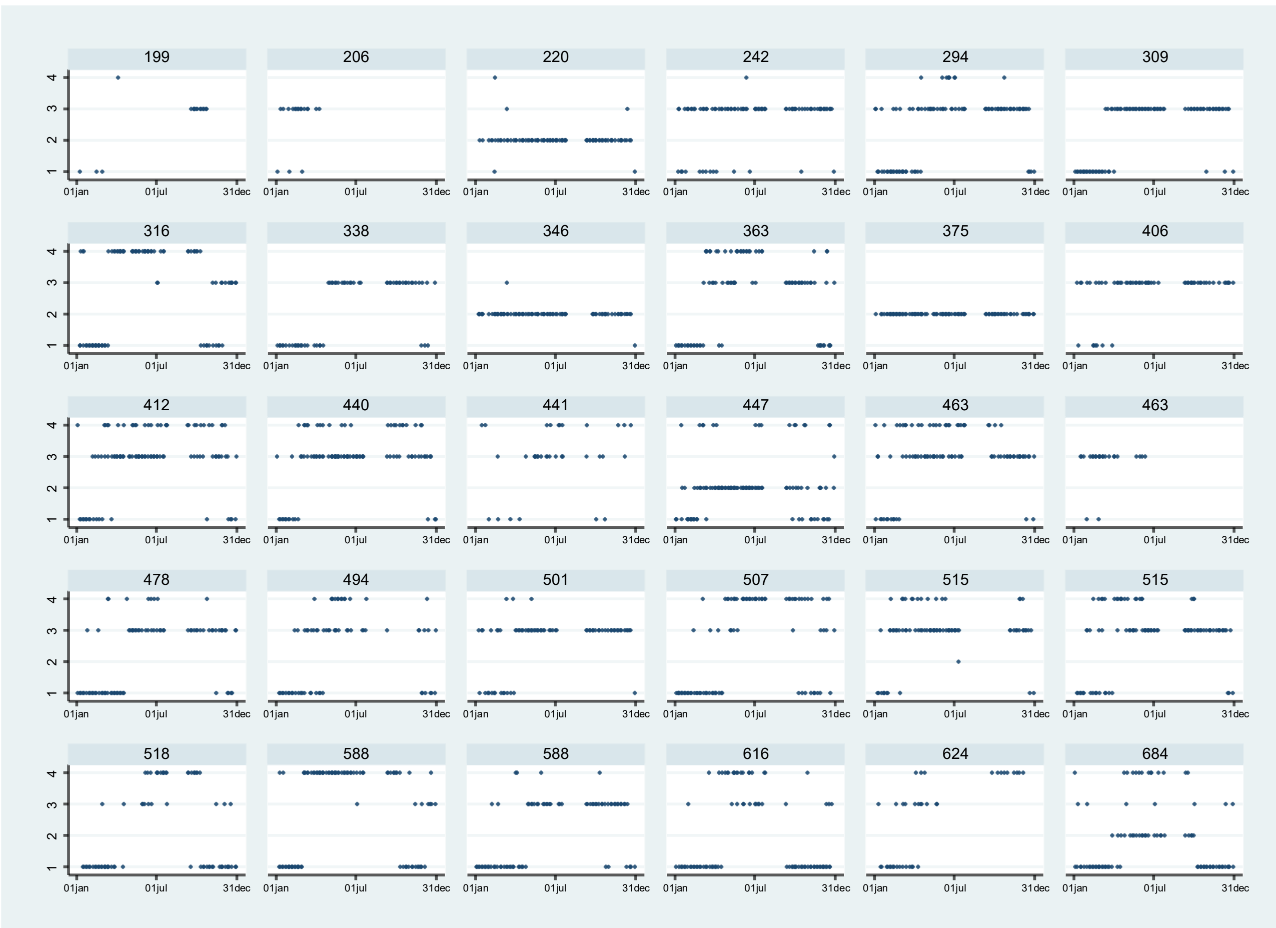
Variable	Coefficient	Std. Err.	p-value
ln *kW*	10.463	4.415	0.018
ln *FT*	0.722	0.532	0.175
ln *NT*	-0.822	0.540	0.128
ln *kW* ln *FT*	-0.238	0.174	0.172
ln *kW* ln *NT*	0.350	0.196	0.073
ln *FT* ln *NT*	0.043	0.064	0.499
ln *kW*^2	-1.775	0.754	0.019
ln *FT*^2	0.172	0.026	0.000
ln *NT*^2	-0.063	0.030	0.034
January	0.108	0.056	0.054
February	-0.074	0.055	0.178
March	-0.114	0.056	0.041
April	-0.143	0.055	0.010
May	-0.172	0.056	0.002
June	-0.402	0.056	0.000
July	-0.274	0.059	0.000
September	-0.083	0.061	0.174
October	-0.160	0.057	0.005
November	-0.016	0.058	0.779
December (ref.)			
Constant	-23.893	12.942	0.065
N		2273	
R squared		0.201	
Wald Chi-Square statistic (19)		703.46	
Prob>Chi-square		0.000	

Table A3 - Average hours at sea and liters of fuel consumed per trip.

Catch profile	Mean hours (fishing + navigation)										
	J	F	M	A	M	J	J	S	O	N	D
Cluster 1	39.0	36.8	32.5	53.9	13.4	21.4	.	25.0	28.3	25.6	34.7
Cluster 2	15.9	16.7	17.6	17.9	28.1	17.8	16.6	18.7	20.3	18.3	18.0
Cluster 3	23.7	25.8	19.6	26.4	33.0	24.2	24.3	21.4	31.4	21.9	26.7
Cluster 4	24.9	23.7	22.3	23.8	26.0	24.8	24.3	23.4	29.2	20.4	24.8
Catch profile	**Mean liters (fishing + navigation)**										
	J	F	M	A	M	J	J	S	O	N	D
Cluster 1	2875.5	2735.7	2517.7	4125.7	457.9	719.5	.	2305.6	2359.9	2127.2	2693.1
Cluster 2	856.5	893.3	1040.1	1105.7	1669.9	1147.9	1030.4	1214.1	1047.1	922.8	963.9

Cluster 3	1635.8	1746.5	1246.6	1822.8	2271.9	1680.4	1636.0	1356.1	1992.3	1505.5	1867.9
Cluster 4	1831.5	1649.8	1662.4	1867.2	1973.0	1839.6	1854.9	1775.2	2253.8	1537.2	1851.6

Figure A1 - Catch profile (Clusters 1-4) per trip for each TBB during the year 2019. Boxes are ordered consecutively based on the engine power (kW) of the vessel (reported at the top).



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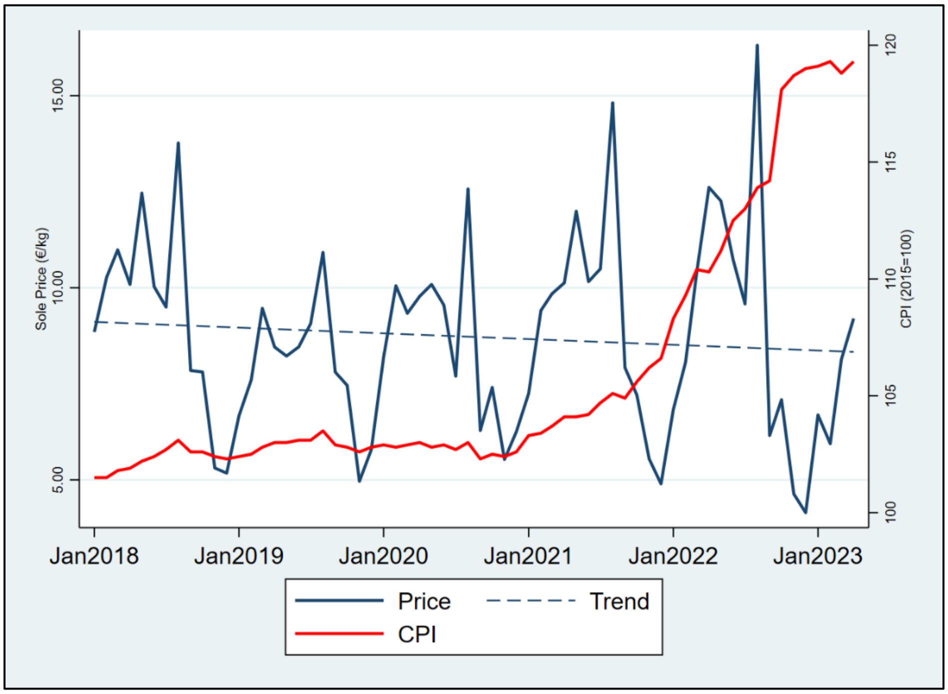
IV

BALANCING ENVIRONMENTAL CONCERNS AND EFFICIENCY IN MEDITERRANEAN FISHERIES: ECONOMICS OF PRODUCTION WITH A LOOK AT MARKET TRENDS

5.1. Introduction

In order to strengthen the sustainability and resilience of European fisheries, the European Commission has recently recalled the importance of reducing the impact of fishing activities on the seabed. This implies that Member States are expected to adopt measures prohibiting mobile bottom fishing in the marine protected areas (MPAs) that are Natura 2000 sites and ensure that by 2030 mobile bottom fishing is phased out in all MPAs (European Commission, 2023a). Being one of the most impacting fisheries in terms of carbon footprint (Sala et al., 2022), seabed damages (Armelloni et al., 2021) and unwanted catches (Pranovi et al., 2001), the Italian *rapido* fishery in the Central/Northern Adriatic Sea (GSA 17) has been indeed subject to increasing effort limitations in recent years (8663 days in 2020, 7443 in 2023). The reduction in fishing effort is expected to generate a decrease in landings which, in turn, should positively affect the price of the most relevant target species, thus addressing the need to maintain prices at appropriate levels by channeling production in order to take advantage of market opportunities (European Commission, 2023a). However, as stressed by NISEA (2022a), the poor performance of several segments of the Italian fleet (including *rapido*) is indeed related to the fact that first sale prices of most species are not keeping up with inflation (Figure 1).

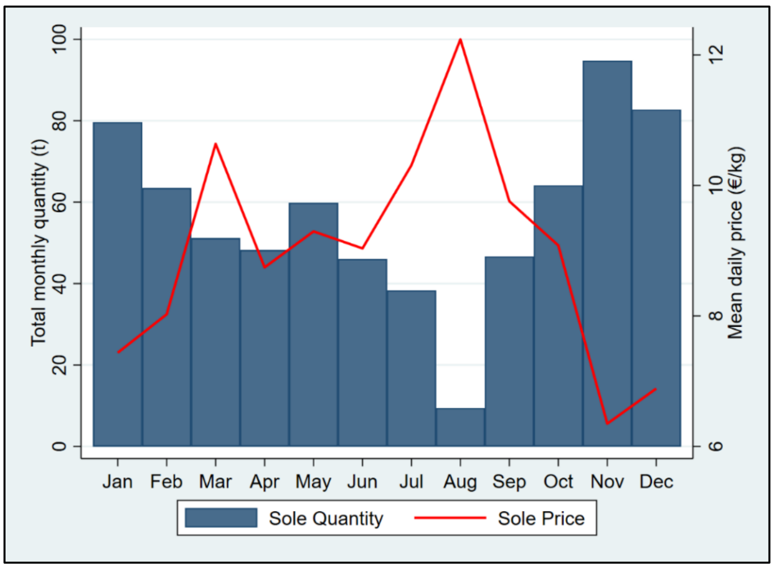
Figure 1 - First sale price of sole at Chioggia Market and Italian consumer price index (CPI). Source: EUMOFA, ISTAT



Being aware that the *rapido* fishery represents a compelling case study due to the substantial environmental issues it is associated with, our focus lies on 31 *rapido* boats (a type of beam trawl) from Chioggia port (Veneto region), which represent approximately 86.1% of the *rapido* fleet in the region and account for 34.1% at the national level (NISEA, 2022b). This fishery- as many others in the Mediterranean Sea (Carpi et al., 2017)- is regulated through inputs control, meaning that management measures aim at reducing pressure on target species by fishing effort reductions. The multiannual management plan in force in the area, aimed at ensuring the sustainability of key demersal fish stocks in the Adriatic Sea, holds particular significance for the long-standing *rapido* trawl fishery operating in the western side of the north-central Adriatic. This fishery, utilizing specialized gear to target flatfish and sediment-dwelling species, has raised environmental concerns due to its invasive nature, impacting macro and meiobenthic communities and indirectly interfering with the distribution of prey species essential for fish stocks (Armelloni et al., 2021). For this reason, the establishment of a five-year (2022-2026) fishing effort regime for bottom otter trawls and *rapido* trawls underscores the commitment to sustainable fisheries management, with effort quotas determined annually based on scientific advice (Recommendation GFCM/43/2019/5).

Fisheries management relying on input controls assumes that all vessels within a fleet have similar levels of efficiency, meaning that limitations in fishing effort are expected to lead to proportionate reductions in fishing mortality. However, if variations in technical efficiency are observed, the effectiveness of management based on using input controls may be impacted (Pascoe and Tingley, 2007). This implies that, in the presence of heterogeneity, a flexible and versatile management framework that takes into account local characteristics (such as specific areas, time periods, and fishers' behavior) as well as market trends of relevant species (Figure 2) could provide a positive supplement to current regulations, which mainly focus on fishing days reduction, a biological ban in the Summer season (approximately six weeks between late July and early September) and other technical measures (MASAF, 2023). In this work we expand previous research on the *rapido* fishery (Pranovi et al., 2015; Russo et al., 2020) by conducting a comprehensive examination that integrates the study of technical efficiency with the assessment of the economic performance of vessels and price formation analysis, supporting potential reforms in current management practices.

Figure 2 – Quantity and price series of sole sold at Chioggia Fish Market in 2019



In the realm of fisheries economics, the evaluation of technical efficiency has emerged as a pivotal tool for assessing the performance and sustainability of fishing operations (Coglan and Pascoe, 2007; Yang et al., 2017; Kiyama and Yamazaki, 2018; Sangün et al., 2018; Gómez and Maynou, 2020; Dağtekin et al., 2021). Nevertheless, several approaches can be found in the literature with regard to the choice of the relevant inputs and outputs on which efficiency measurement should be based. While input variables selection is not our objective, in this study we delve into the intriguing dimension of comparing technical efficiency scores when output is measured in terms of weight versus the value of landings. This choice is not merely an academic exercise; rather, it reflects the complex interplay of market dynamics, risk aversion, and decision-making strategies within the fishing industry. By assessing the performance of vessels on the basis of both a physical and monetary measure, our study aims to investigate the economic and behavioral underpinnings that drive fishing operations, ultimately shedding light on the adaptability of vessels in the face of changing market conditions and ecological challenges. The intuition behind this study builds on previous research by Herrero and Pascoe (2003), who applied Stochastic Frontier Analysis (SFA) to study the efficiency of the Spanish South-Atlantic trawl fishery using both revenue and landings weight as dependent variables. Their findings suggest that fishers use a spectrum of strategies, and only a minority are primarily concerned with maximizing catch weight. These strategy differences may be indicative of varying risk preferences, with the more risk-averse fishermen opting for a trade-off that ensures a more predictable catch quantity at the expense of potential value. We expand this type of efficiency analysis by incorporating an investigation of seasonality effects and the relationship between prices and quantities of primary species in the fishery in order to offer insights for maintaining price levels at an optimal range and capitalizing on market opportunities.

The research questions behind our study are therefore the following. First, are there any differences in terms of efficiency among *rapido* vessels depending on the output variable used (landings weight or value)? Second, considering both the efficiency of vessels and market trends of target species, which management approaches can be proposed to improve the economic profitability of the fishery while ensuring the sustainable use of marine resources? It is important to emphasize that while this analysis primarily concentrates on enhancing short-term efficiency, it is essential for future management interventions to be in harmony with the fishery's long-term sustainability goals. These sustainability objectives encompass biological considerations, which, though not covered in this article, are integral to a comprehensive fisheries management approach.

5.2. Methodology

Technical efficiency can be defined as the ability of an agent to maximize the output given a set of inputs (output orientation) or minimize the use of inputs required to produce a given output (input orientation), with the former formulation being the most used in fisheries (Pascoe and Tingley, 2007). Considering the stochastic nature of the production process at sea, we apply SFA due to its ability to account for statistical noise through the incorporation of random errors (Herrero and Pascoe, 2003). Following Battese and Coelli (1995), we apply the stochastic frontier production function

$$y_{it} = f(x_{it}; \alpha) + v_{it} - u_{it} \tag{1}$$

where y_{it} denotes the vessel output per trip (landings in weight and value), x_{it} are the inputs to production (fishing time and engine power of the vessel), v_{it} denotes stochastic noise and u_{it} represents technical inefficiency. The random errors are assumed to be i.i.d. following a normal distribution $N(0, \sigma_v^2)$, while several distributional assumptions exist regarding the inefficiency component. A common approach in the fisheries literature is to model it as a function of exogenous variables (Pascoe and Coglan, 2002). The inefficiency determinants function follows the form $u_{it} = \delta_0 + z_{it}\delta + w_{it}$ where z_{it} is a vector of vessel-specific characteristics affecting efficiency, δ is a vector of parameters, and w_{it} is the i.i.d. error term. Estimates of technical efficiency per trip by each vessel are given by

$$TE_{it} = e^{-u_{it}} = e^{-(\delta_0 + z_{it}\delta + w_{it})} \tag{2}$$

describing the ratio of the actual output over the maximum that could be obtained given the inputs employed (Battese and Coelli, 1995; Fousekis and Klonaris, 2003). The parameters of the stochastic frontier and the model for inefficiency effects are estimated simultaneously using the maximum likelihood method. In addition, to estimate the fishing technology's relationship between inputs and output, a functional form must be selected. A common option is represented by the Cobb-Douglas production function, which is a special case of the more general Translog function. The latter is usually considered as the most flexible form (Van Nguyen et al., 2019) because it enables elasticities of substitution to vary, while the Cobb-Douglas maintains a constant elasticity of production across all inputs and the elasticity of substitution is fixed at 1, meaning that the degree of substitutability among inputs remains constant (Squires and Kirkley, 1999). Key tests to be conducted hence include the choice of the functional form (Cobb-Douglas vs Translog), the existence of a frontier and the distribution of inefficiency (Pascoe et al., 2003).

Concerning market dynamics of relevant species, we investigate the role of *i*) sold quantities, *ii*) day of the week and *iii*) seasonality in influencing the price of fish combining the inverse demand modelling and hedonic pricing approach. The hedonic pricing approach posits that products are comprised of various traits and are esteemed for their utility-inducing features. The market value therefore mirrors the amalgamation of these attributes, which, notably lack a direct price. Consequently, it becomes viable to assess the worth of these constituent attributes by scrutinizing systematic price fluctuations (Rosen, 1974), making the hedonic price method a valuable tool for assessing price premiums associated with quality attributes in the agri-food market (Costanigro et al., 2011). On the one hand, demand models in fisheries generally assume that the supply of fish is exogenously determined due to the influence of external factors not under fishers' control (weather and water conditions, biological shocks) and because fish is a perishable item that needs to be sold quickly (Nielsen, 2000; Asche and Hannesson, 2002; Jaffry et al., 2005). On the other, hedonic models- specifying the price of fish as a function of its attributes- are also frequently applied in fisheries economics in order to examine the value of quality attributes such as size, freshness, origin and fishing gear (Kristofersson and Rickertsen, 2004; Asche and Guillen, 2012;

Krigbaum and Anderson, 2021). Combining the two approaches following Guillen and Maynou (2015), the model is written in its general form as

$$P_{it} = f(a_1, \dots, a_n) \tag{3}$$

where the price of fish *i* at time *t* is a function of vector $A = (a_1, \dots, a_n)$ including the variables of interest, mainly quantities and temporal patterns. The function permits an evaluation of the significance of each attribute while keeping all other attributes constant. Attribute a can be measured either on a continuous scale or by using a dummy variable, depending on its nature (Roheim et al., 2011).

5.3. Data description and econometric model

The dataset contains information on 2,404 trips by 31 vessels during 2019 (Table 1) and it was built from AIS data provided by the Italian Coast Guard, which have been matched with the EU Fleet Register to retrieve information on the characteristics of vessels. Data on landings and daily prices for the most relevant species (sole, cuttlefish, purple dye murex, caramote prawn, spottail mantis shrimp, queen scallop and great Mediterranean scallop)- covering approximately 80% of the total landed value by the fleet in the basin (STECF, 2022)- are used to compute trip revenues. Detailed information on the procedure to build the dataset can be found in Russo et al. (2020). With regard to the study of technical efficiency, the estimated equations are given by

$$\ln LF_{it} = \alpha_0 + \alpha_T \ln T_{it} + \alpha_{KW} \ln kW_i + \alpha_{TT} (\ln T_{it})^2 + \alpha_{KWKW} (\ln kW_i)^2 + \alpha_{TKW} (\ln T_{it} \cdot \ln kW_i) + \alpha_4 D_t + v_{it} - u_{it} \tag{4}$$

where LF_{it} are the landings of fish, measured firstly in weight (kg) and secondly in value (€), T_{it} is fishing time, kW_i denotes power and D_t is a monthly dummy describing stock fluctuations. These input variables capture the contribution of fishing effort and stock availability to production (Andersen, 2002). Technical efficiency effects are then defined by

$$u_{it} = \delta_0 + \delta_Y A_i + \delta_L LC_i + w_{it} \tag{5}$$

where A is the boat age and LC is the length class. Age is assumed to be an exogenous factor negatively affecting efficiency (Van Nguyen *et al.*, 2019), while the length class is an additional criterion for fishing opportunities allocation according to national regulations (MASAF, 2023), based on the definition of effort groups as a combination of gear type and vessel length class ("fleet segment") (Recommendation GFCM/43/2019/5).

Concerning the analysis of fish prices at Chioggia Market[32], the model is presented in a double log form in order to facilitate the interpretation of the quantity coefficient as elasticity (Carrol et al., 2001). The model to be estimated is therefore specified as

$$\ln P_{it} = \beta_0 + \beta_1 \ln Q_{it} + \beta_2 DW_t + \beta_3 M_t + \beta_4 YC_t + \varepsilon_{it} \tag{6}$$

where the price of fish *i* at time *t* is a function of the quantity sold at the market *Q*, the day of the week *DW*, the month *M* and the year *YC*. The constant term β_0 indicates the price for the base category while ε_{it} is a normally distributed random error term. First, the Augmented Dickey-Fuller test indicates that null hypothesis of non-stationarity can be rejected for all seven time series of fish prices. Then, having detected heteroskedasticity and autocorrelation based on the White's and Breusch-Godfrey LM tests, the parameters of Equation 6 are estimated by OLS using Newey–West standard errors with one weekday lag (Newey and West, 1987; Greene, 2003). Lastly, checking for multicollinearity, the Variance Inflation Factors test (Chatterjee and Hadi, 2006) indicates that the selected variables can be included together in the model (Table A1).

Table 1 – Summary statistics per fishing trip (year 2019)

Variable	25° Percentile	Median	75° Percentile	Mean	Std.Dev.
Engine power (kW)	338.00	441.00	515.00	433.17	121.00
Length (meters)	21.70	23.00	24.37	22.87	2.47
Age (years)	25.00	29.00	35.00	31.47	9.96
Fishing time (hours)	12.11	17.55	27.64	19.48	10.36
Fuel (liters)	717.52	1179.84	2095.38	1458.38	963.50
Landings weight (kg)	210.63	341.98	552.75	423.53	357.97
Landings value (€)	1675.13	2718.22	4292.69	3273.53	2721.71
Rapido vessels analysed = 31; N = 2404 observations.					

[32] Daily fish prices for the years 2019 and 2020 have been provided by representatives of Chioggia Fish Market.

5.4. Results

First, it is important to provide a general overview of seasonality effects concerning landings and prices of the seven species under consideration. From Table 2 we can observe that in *rapido* fishery of Chioggia in the year 2019, sole is by far the most relevant species in terms of weight (432,685 kg), followed by queen scallop (219,352 kg) and cuttlefish (169,736 kg), while great Mediterranean scallop (89,081 kg), murex (51,581 kg), caramote prawn (42,721 kg) and mantis shrimp (13,018 kg) play a secondary role. Nevertheless, taking into account average monthly prices, it emerges that the contribution of each species to the total value of landings may not correspond to its importance measured in weight terms. For instance, queen scallop represents 22% of landings, but its low average price (fluctuating between 3.80 €/kg in September and 5.83 €/kg in March) implies that its contribution to total value decreases to 13% of the total. On the other hand, despite its remarkable fluctuations in price (from 7.43 €/kg in November to 16.93 €/kg in July), cuttlefish landings basically have the same relevance in terms of contribution to both weight and value (around 17% of the total).

Before providing for efficiency estimates, we show the magnitude and statistical significance of the parameters of the production function and inefficiency effects (Table 3) and conduct some tests concerning the structural form of both the weight and value models. First, it should be noted that the parameter lambda- which indicates the ratio of the standard deviation of the inefficiency term σ_u to the standard deviation of the stochastic term σ_v- is statistically significant and different from zero (p-value < 0.01), highlighting the greater importance of technical inefficiency as opposed to random shocks in contributing to production shortfalls from the frontier (Ogundari and Akinbogun, 2010). Second, a likelihood ratio (LR) test comparing the Cobb Douglas production function with the more comprehensive Translog specification was performed. The LR statistics of 46.44 (value model) and 34.45 (weight model) imply that the null hypothesis ($\alpha_{TT} = \alpha_{KWKW} = \alpha_{TKW} = 0$) is rejected ($p$-value < 0.01), hence a flexible model including interactions among inputs and relaxing the restrictive Cobb Douglas assumptions is a better representation of the production process taking place in the fishery for both the weight and value specifications (Kirkley et al., 2003). Third, testing for the influence of vessel-specific attributes on inefficiency, rejection of the null hypothesis ($\delta_Y = \delta_L = 0$), indicates that the formulation of the stochastic frontier is more appropriate than a truncated normal model with mean δ_0 (Greenville et al., 2006) for both Model 1 (output as kg of fish) and Model 2 (output as € of fish). The results of the likelihood ratio tests are shown in Table A2.

The mean efficiency scores for the value and weight-based models are 0.647 and 0.651, respectively, with the dominance of landings-based scores being most pronounced in October and November (Table 4). This difference, although small, suggests that on average Model 1 scores are higher than Model 2 scores, as confirmed by the Wilcoxon signed rank test on the equality of distributions (z-statistic = -2.925, p-value < 0.01) This confirms the importance of performing an efficiency analysis relating inputs and output in the production process of the fishery, since the intermonth comparison of revenues generated by landings provides only a partial representation of the profitability of the sector. A Kruskall-Wallis test reveals that the difference between value-based and weight-based scores is significantly different among vessels (χ^2 (30) = 407.835, p-value < 0.01), hence indicating heterogeneity in the ability of fishers to capitalize on revenue opportunities from fishing activity. Overall, we highlight the potential of our analysis to provide a comprehensive assessment of the economic performance of the fishery by simultaneously i) following the evolution of efficiency scores throughout the year and ii) juxtaposing weight-based and value-based scores from Model 1 and 2, respectively. For instance, while the month of October may look as a profitable period due to the increase in landings (90,641 kg) and revenues (730,048 €) after the Summer ban (e.g. 57,236 kg of landings and 423,098 € of value in July) (Table 2), the intense fishing activity characterized by long time at sea and great fuel consumption (Table 5) leads to a greater usage of production inputs which negatively impacts the overall efficiency of the fishery.

While the choice of a unique output measure of efficiency analysis- monetary (i.e. value) or physical (i.e. weight)- is open to debate, the great fluctuations in the price of target species shown in Table 2 point out the need to understand the influence of fish supply and temporal factors. In this sense, the estimation results reported in Table 6 provide interesting insights concerning the behavior of fish prices at Chioggia Market. First, the role of sold quantities seems to have a negative effect on price levels, as dictated by economic theory. This holds for six out of seven species under analysis (except for queen scallop), with mantis shrimp prices being highly responsive to fluctuations in quantity sold. This indicates that changes in the quantity of mantis shrimp available in the market have a substantial impact on its price. On the contrary, queen scallop stands out as an exceptional case within the study, as it does not exhibit significant price elasticity. Nevertheless, the year 2020 demonstrates a stronger influence on queen scallop prices compared to other species.

Furthermore, a prominent pattern among various species is the tendency for prices to be higher at the start of the week (the opening day is Tuesday, as the market is closed on Sunday and Monday) and gradually decline towards the end. This presents a valuable opportunity for fishers to strategize their actions accordingly. Lastly, the influence of seasonality on fish prices plays a significant role in determining price fluctuations, since it reflects the changes in the availability of each stock, which can also be detected from Table 2. As an example, the relevant volumes of great Mediterranean scallop landed in Spring are associated to a negative and significant coefficient for the months of April, May and June. Nevertheless, we remark that the availability of longer time series of market prices would notably improve the robustness of our results, which consider only two years (including the period affected by the COVID-19 pandemic).

Table 2 – Monthly variations in landings and prices in Chioggia (year 2019)

Month	Sole		Cuttlefish		Murex		Caramote prawn		Mantis shrimp		Queen scallop		Great Med. scallop	
	Total catch *(kg)*	Price *(€/kg)*	Total catch *(kg)*	Price *(€/kg)*	Total catch *(kg)*	Price *(€/kg)*	Total catch *(kg)*	Price *(€/kg)*	Total catch *(kg)*	Price *(€/kg)*	Total catch *(kg)*	Price *(€/kg)*	Total catch *(kg)*	Price *(€/kg)*
Jan	54,698	8.25	47,756	7.66	2,022	3.46	4,454	14.57	3,634	6.39	18,085	4.65	8,177	9.71
Feb	43,264	9.25	35,482	8.12	991	3.38	3,604	15.06	3,590	8.48	21,244	4.20	8,206	10.70
Mar	29,615	10.18	18,984	8.61	2,792	3.25	3,431	19.08	1,264	9.57	16,139	5.83	9,257	9.26
Apr	37,677	9.76	10,243	7.94	5,490	2.96	4,662	21.99	849	7.97	30,893	5.43	11,287	8.65
May	35,584	9.66	1,993	8.67	6,553	2.88	3,179	21.83	163	7.81	29,420	5.14	10,515	8.93
Jun	25,940	9.37	458	11.18	5,431	3.23	1,770	19.98	35	7.47	26,543	4.55	10,088	8.02
Jul	23,096	9.22	212	16.93	3,245	3.17	1,259	20.60	128	5.84	21,966	4.36	7,331	10.10
Sep	30,313	8.97	4,285	9.04	4,326	3.19	4,055	18.22	416	5.67	12,473	3.80	6,056	11.28
Oct	43,798	9.15	11,906	8.26	6,668	2.90	3,392	16.45	819	6.57	15,686	3.95	8,372	10.56
Nov	53,670	6.98	16,168	7.43	6,118	2.30	7,838	15.50	595	5.43	11,408	4.00	4,317	11.97
Dec	55,030	7.35	22,250	8.98	7,945	2.68	5,077	19.29	1,525	6.31	15,496	5.46	5,474	13.96
Note: Landings indicate the sum of sampled fishing trips. Prices come from Chioggia Fish Market.														

Table 3 – Maximum likelihood estimates of the parameters of the stochastic frontier models

Parameter	Model 1 Weight as dependent variable	Model 2 Value as dependent variable
Frontier model		
ln *kW*	8.282*** (-4.94)	6.625*** (-4.11)
ln *T*	1.063** (-2.26)	0.975** (-2.17)
ln *kW* * ln *T*	-0.25 (-1.58)	-0.24 (-1.63)
(ln *kW*)^2	-1.409*** (-4.75)	-1.115*** (-3.92)
(ln *T*)^2	0.0412** (-2.04)	0.0870*** (-4.56)
February	-0.204*** (-3.38)	-0.142** (-2.47)
March	-0.410*** (-6.54)	-0.216*** (-3.60)
April	-0.341***	-0.249***

	(-5.51)	(-4.23)
May	-0.413*** (-6.57)	-0.309*** (-5.12)
June	-0.534*** (-8.31)	-0.527*** (-8.57)
July	-0.559*** (-8.40)	-0.439*** (-6.95)
September	-0.372*** (-5.50)	-0.310*** (-4.81)
October	-0.376*** (-5.91)	-0.283*** (-4.65)
November	-0.04 (-0.59)	-0.188*** (-3.05)
December	-0.08 (-1.25)	-0.09 (-1.58)
Constant	-18.70*** (-3.89)	-12.04*** (-2.61)
Inefficiency model		
ln *A*	28.40** (-2.38)	39.22 (-1.31)
Length > 24m	-5.51 (-1.36)	-3.14 (-0.59)
Constant	-139.0** (-2.39)	-205.80 (-1.30)
Log-likelihood	-2615.24	-2534.26
Lambda	9.6*** (9.43)	13.6*** (5.57)
Note: Standard errors in parentheses.		

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4 - Technical efficiency distribution by month

Month		**Weight efficiency score**		**Value efficiency score**	
	N	Mean	St.Dev	Mean	St.Dev.
January	234	0.663	0.163	0.659	0.166
February	251	0.648	0.178	0.651	0.173
March	222	0.655	0.170	0.652	0.169
April	233	0.650	0.170	0.649	0.166
May	252	0.637	0.186	0.636	0.184
June	217	0.638	0.190	0.636	0.191
July	184	0.648	0.186	0.650	0.189
September	174	0.656	0.175	0.650	0.187
October	216	0.645	0.186	0.636	0.201
November	202	0.661	0.160	0.652	0.178

December	211	0.656	0.180	0.650	0.188
Total	**2396**	**0.651**	**0.177**	**0.647**	**0.181**

Table 5 – Monthly variations in fishing time and fuel consumption by sampled *rapido* vessels (year 2019)

Months		**Fishing time (hours per fishing trip)**	**Fuel (litres per fishing trip)**
J	Mean	24.0	1838.9
	St.Dev.	11.6	1137.9
F	Mean	22.6	1690.7
	St.Dev.	11.8	1113.7
M	Mean	19.3	1475.3
	St.Dev.	10.4	979.6
A	Mean	20.6	1553.6
	St.Dev.	11.3	1029.1
M	Mean	15.1	1120.6
	St.Dev.	8.0	739.7
J	Mean	17.7	1302.3
	St.Dev.	9.7	843.1
J	Mean	16.8	1226.4
	St.Dev.	8.3	809.7
S	Mean	15.9	1164.4
	St.Dev.	7.3	691.7
O	Mean	21.4	1543.0
	St.Dev.	10.3	936.3
N	Mean	17.5	1309.0
	St.Dev.	7.6	773.7
D	Mean	22.1	1698.6
	St.Dev.	10.9	1031.7

Table 6 – Effect of quantities, day of the week, month and year on the price of main species

Parameter	**Sole**		**Cuttlefish**		**Murex**		**Caramote prawn**		**Mantis shrimp**		**Queen scallop**		**Great Med. scallop**	
	coef.	*p-value*	coef.	*p-value*	coef.	*p-value*	coef.	*p-value*	coef.	*p-value*	coef.	*p-value*	coef.	*p-value*
Q	-0.03	*0.018*	-0.02	*0.004*	-0.04	*0.000*	-0.06	*0.000*	-0.13	*0.000*	0.00	*0.959*	-0.08	*0.000*
DW (ref: Thu)														
Tue	0.09	*0.000*	0.09	*0.001*	0.01	*0.658*	0.04	*0.076*	0.17	*0.000*	0.01	*0.814*	0.03	*0.203*

Wed	-0.01	*0.723*	0.01	*0.563*	-0.02	*0.325*	-0.03	*0.094*	-0.03	*0.404*	-0.10	*0.015*	-0.05	*0.017*
Fri	0.00	*0.901*	0.01	*0.794*	0.00	*0.767*	-0.03	*0.176*	0.02	*0.454*	-0.08	*0.059*	-0.02	*0.352*
Sat	-0.09	*0.015*	-0.01	*0.659*	-0.15	*0.000*	-0.09	*0.001*	-0.03	*0.426*	-0.31	*0.000*	-0.18	*0.000*
M (ref: Jan)														
Feb	0.11	*0.001*	0.05	*0.055*	-0.03	*0.168*	0.04	*0.261*	0.21	*0.000*	-0.10	*0.152*	0.08	*0.072*
Mar	0.17	*0.010*	0.09	*0.022*	-0.11	*0.014*	0.22	*0.000*	0.26	*0.000*	0.04	*0.707*	-0.05	*0.385*
Apr	0.11	*0.006*	0.01	*0.859*	-0.15	*0.000*	0.33	*0.000*	0.04	*0.435*	0.00	*0.966*	-0.09	*0.023*
May	0.11	*0.014*	0.07	*0.011*	-0.15	*0.000*	0.32	*0.000*	0.11	*0.009*	-0.05	*0.559*	-0.06	*0.097*
Jun	0.10	*0.001*	0.23	*0.000*	-0.05	*0.083*	0.23	*0.000*	0.14	*0.000*	-0.09	*0.202*	-0.14	*0.001*
July	0.07	*0.082*	0.56	*0.000*	-0.07	*0.006*	0.25	*0.000*	-0.11	*0.028*	-0.05	*0.390*	0.06	*0.243*
Aug	0.33	*0.000*	0.44	*0.065*			0.33	*0.000*	0.15	*0.002*				
Sep	0.02	*0.687*	0.11	*0.000*	-0.06	*0.092*	0.17	*0.000*	-0.23	*0.004*	-0.20	*0.015*	0.16	*0.000*
Oct	0.07	*0.047*	0.05	*0.146*	-0.13	*0.000*	0.09	*0.021*	-0.04	*0.423*	-0.17	*0.022*	0.10	*0.023*
Nov	-0.18	*0.000*	-0.05	*0.083*	-0.28	*0.000*	0.01	*0.700*	-0.21	*0.000*	-0.15	*0.045*	0.16	*0.005*
Dec	-0.11	*0.002*	0.11	*0.002*	-0.18	*0.000*	0.21	*0.000*	-0.03	*0.648*	0.12	*0.294*	0.31	*0.000*
Y (ref: 2019)														
2020	0.03	*0.154*	0.08	*0.000*	-0.16	*0.000*	0.00	*0.860*	-0.12	*0.000*	-0.46	*0.000*	0.02	*0.280*
Const	2.43	*0.000*	2.28	*0.000*	1.81	*0.000*	3.04	*0.000*	2.87	*0.000*	2.00	*0.000*	2.82	*0.000*
Obs	481		447		408		427		485		405		404	

5.5. Discussion and conclusions

Depending on the priority weightings placed by management institutions (economic efficiency, stock preservation), this type of analysis can support the selection of the most appropriate temporal units for future regulations involving a reduction in fishing days. To ensure that these have no impact on market supply and do not result in the closure of established commercial circuits, it is essential to consider both the distribution of fishing time limitations throughout the year in addition to the fishing time reduction itself (Sánchez Lizaso et al., 2020). On the other hand, even if the introduction of quotas for demersal species has been traditionally rejected in the Mediterranean Sea due to the multispecies nature of most fisheries (Mulazzani et al., 2018)[33], it is reasonable to presume that setting a total allowable catch (TAC) for sole in the Autumn/Winter season would prevent the fall in prices that occurs in November (6.35 €/kg) and December (6.89 €/kg), especially considering that sole represents about 50% of landings in these months. Similarly, transferring effort restrictions to periods characterized by lower efficiency (e.g. May, June, October) can improve the economic performance of the fishery by means of *i*) reduced inputs usage and *ii*) higher prices arising from the reduced fish offer in the market.

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[33] A relevant exception is represented by the recent introduction of catch limits for giant red shrimp and blue and red shrimp in the Levant Sea (Recommendation GFCM/45/2022/7).

Moreover, inspection of Table 4 reveals that landings and value efficiency scores move in the same direction from month to month, meaning that increases (or decreases) in the former are usually reflected by increases (or decreases) in the latter. This suggests that fishers have a limited ability to adapt to changing prices through strategic behaviour while they tend to be greatly affected by changes in stock availability. Nevertheless, we remark that it is essential to further extend the analysis considering the biological cycles of target species, such as reproduction periods and areas, when contemplating any shift of fishing days from less efficient periods to more productive ones. The increasing use of georeferenced data describing fishing activity (Russo et al., 2020) is a promising research field for the integration of biological and ecological aspects in the study of technical efficiency, since it allows the identification of fishing areas characterized by different levels of efficiency, therefore informing potential management interventions aimed at spatially allocating fishing effort.

With reference to the intermonth comparison of efficiency scores, it is worth highlighting that the average October value-based score is indeed lower if compared to *i*) the months of September and November- which are both characterized by reduced inputs usage – and *ii*) its weight-based score monthly counterpart from Model 1. This reminds us of the well-known “race to fish” problem at the start of a new fishing season, an unintended consequence arising from effort restrictions involving temporal closures (Colwell et al. 2019). It is also worth noticing that the negative coefficient associated to the age of the *rapido* seems to affect efficiency estimates only in Model 1, meaning that- holding constant all other variables- older vessels are not necessarily less efficient in generating value during a fishing trip. The discrepancy between the two models might reflect the influence of other factors not included in the present analysis, like technological developments on board or skipper skill (Pascoe and Coglan, 2002), both of which are more difficult to regulate and monitor.

As already mentioned in the presentation of Table 6, further analysis investigating quantity-price relationships in the fishery would benefit from the inclusion of more recent data. This would be especially relevant in the case of queen scallop, which is the only species that does not show a significant elasticity. The reasons behind this observation warrant further exploration. For instance, this anomaly might be attributed to an oversupply in the market, potentially influenced by external factors such as the COVID-19 pandemic[34].

Further refinements of our analysis might take into consideration different approaches concerning the treatment fish stock fluctuations and their incorporation into the production frontier. The solution adopted here is to control for the influence of seasonal variations in fish availability using dummies (Pascoe and Robinson, 1998; Fousekis and Klonaris, 2003; Vinuya, 2010). Another approach would be to use information from stock

[34] Another contributing factor can be related to trade dynamics. In 2020, Italian imports of frozen scallops, including queen scallops and other varieties, increased compared to the previous year, as reported by the Italian National Institute of Statistics (COEWEB, 2023). This surge in imports could have added to the supply of queen scallops in the market, potentially contributing to the price decrease observed in 2020.

assessments, but this is not available for all the seven species under analysis at weekly or monthly level during the year 2019. Efficiency studies that include spawning stock biomass data among the control variables are usually based on longer time series at the yearly level (Yang et al., 2017). Alternative approaches include the computation of indexes of stock abundance based on relative catch rates (Pascoe and Tingley, 2007).

Lastly, we recommend that future research should investigate the expected economic effects following the implementation of a TAC system in the fishery. Intuitively, setting a TAC in the initial month following the fishing closure, it is expected that prices increase. Similarly, as the stock does not deplete immediately and is carried over to the subsequent month, there is a surplus stock in the sea, potentially leading to higher efficiency but lower prices in the following month. Therefore, we suggest that future studies should incorporate similar simulations to comprehend how maximum profits can be achieved while keeping catch levels constant. Considering the complexities involved in such a system involving both output and input restrictions, additional examination of the feasibility of a system of Individual Transferable Quotas (ITQs) deserves attention (Mulazzani et al., 2018). Furthermore, our findings suggest that there may be room for optimizing the volume and value of landings by considering more flexible scheduling of fishing days. For instance, allowing fishers to choose the fishing days throughout the week, rather than adhering strictly to the current weekend restrictions, or dividing the 6-week summer ban into alternative time periods. However, it is essential to acknowledge that the feasibility of such scheduling adjustments must be carefully evaluated by biologists and experts in fisheries management, especially considering the complexities linked to the selection of a seasonal fishing ban in multispecies fisheries. Indeed, stock assessment forms by the General Fisheries Commission for the Mediterranean (GFCM) indicate that there is limited concurrence in the reproductive season of relevant species like sole (Fall-Winter), cuttlefish (Spring-Summer), spottail mantis shrimp (Winter-early Spring), murex (June-July) and caramote prawn (Spring-Summer) in the GSA 17- which implies that any temporal modifications of the fishing season should take into account the current stock status and characteristics of the species involved. These potential reforms could offer a valuable avenue for enhancing the sustainability and profitability of the Chioggia *rapido* fishery while maintaining a balance with ecological considerations. Similar considerations were investigated by Russo et al. (2017) in their analysis of alternative management scenarios of demersal fisheries in Ionian Sea, where the adoption of seasonal and differentiated (rotated) fishing bans for trawlers- coupled by a temporal stop for small-scale fleets- led to positive effects both from a biological (i.e. increase in spawning stock biomass) and economic (i.e. rise in revenues) perspective. As the use of the BEMTOOL platform allowed the authors to model and forecast the long run effects of different management trajectories, our short-term analysis could be further enriched in a bioeconomic framework.

In summary, we highlight the potential of integrating efficiency and price formation analysis to understand whether there are any missed opportunities to generate value in the *rapido* fishery. Moreover, this type of study can be also replicated in other contexts, in order for fisheries management policies to address the specific socio-economic conditions of the coastal communities involved. While the biological dimension is not considered in this article, our investigation can provide a practical starting point to plan potential reforms of fisheries management in the GSA 17 from an economic perspective. Similarly, the proposed methodological approach has the potential to inform those policies requiring the use of multidisciplinary tools, such as the implementation of Marine Spatial Planning in Italian waters (Manea et al., 2019; Menegon et al., 2023). Furthermore, the influence of market dynamics in shaping the economic efficiency of the fishing sector, as revealed in this study, underscores the necessity for renewed market regulation and organization, wherein a significant role could be played by Producer Organizations (European Commission, 2023a). Considering the overexploitation condition of several stocks in the Mediterranean Sea, including the GSA 17 (FAO, 2023), we stress the relevance of promoting an ecosystem-based approach to fisheries management that takes into account both socio-economic and environmental concerns (Long et al., 2015; European Commission, 2023b). If on the one hand it is argued that the former dimension has been experiencing a historical disregard by European fisheries management (Cardinale et al., 2017; Carpi et al., 2017; Drouineau et al., 2023), major challenges posed by ecosystems degradation, climate change and arrival of alien species (Strafella et al., 2015; Grilli et al., 2020; Domina, 2021) require future policies in the Northern Adriatic Sea to gain support from a wide range of stakeholders, fishers included. In accordance with the biological needs of the species targeted by *rapido* trawlers, the allocation of fishing opportunities during the year based on efficiency and market trends can be a first step in this direction. Recently developed initiatives and studies aimed at assessing the socio-economic impacts of management interventions in the Mediterranean Sea (Prellezo and Villasante, 2023) and strengthening fishers' participation in decision-making processes (Malvarosa et al., 2023) indicate the potential for broad stakeholder engagement and increased involvement of the fishing industry.

5.6. Appendix

Table A4 – Results of statistical tests for the price model (source: 2019 and 2020 daily prices from Chioggia Fish Market)

Species	Augmented Dickey-Fuller test		White test		Breusch-Godfrey LM test		VIF
	t-statistic	*p-value*	t-statistic	*p-value*	t-statistic	*p-value*	mean value
Sole	-6.09	0.00	210.03	0.00	97.04	0.00	1.74
Cuttlefish	-4.41	0.00	179.17	0.00	53.04	0.00	1.91
Murex	-3.70	0.00	126.31	0.00	39.43	0.00	1.66
Caramote prawn	-3.90	0.00	140.21	0.00	110.91	0.00	1.76
Mantis shrimp	-7.68	0.00	209.06	0.00	88.55	0.00	1.72
Queen scallop	-6.09	0.00	244.64	0.00	30.83	0.00	1.64
Great Mediterranean scallop	-4.04	0.00	139.22	0.00	214.94	0.00	1.66

Table A2 – Model specification tests

H_0 restrictions	Model 1 Likelihood ratio	Model 2 Likelihood ratio	Number of restrictions	Critical χ^2 $(\alpha = 0.01)$
Cobb Douglas production function	34.45	46.44	3	10.50
Truncated normal distribution	61.56	39.29	2	8.27
Note: critical values are taken from Kodde and Palm (1986)				

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CONCLUSIONS

This thesis represents a comprehensive exploration of European and Mediterranean fisheries from various perspectives, adopting different methodological approaches derived from the economic literature and trying to fill existing knowledge gaps with regard to the valuation of the fishing sector.

The dynamic interplay between market and non-market values in fisheries is a central theme of this thesis. The first two chapters delve into non-market values by investigating the positive externalities that fisheries bring to tourism, coastal viability, and the cultural fabric of coastal regions. These studies acknowledge that the societal importance of fisheries is only partially captured in terms of readily available monetary measures, such as the gross value of landings. Provided that the respect of sustainable management of stocks is assured, coastal communities can benefit from a wider range of positive externalities by fishing activities, especially in the case of small-scale fisheries. By assessing these non-market values, Chapters I and II shed light on the multifunctionality of fisheries and how the socio-economic role of the sector goes beyond market transactions.

In contrast, the latter two studies are more market-oriented, focusing on efficiency and economic considerations. However, these market-based analyses are intricately tied to sustainability due to the integration of stock conditions among the key variables explaining the production process taking place in the fishery. Chapters III and IV hence seek to understand how economic returns can be maximized, ensuring that our fishing practices *i*) remain ecologically responsible in terms of carbon emissions while *ii*) taking advantage of market opportunities in terms of seasonality effects. By identifying more efficient strategies and price formation dynamics, the findings of these articles provide a basis for aligning market interests with long-term sustainability goals.

Despite addressing different themes, the practical implications outlined in the four chapters of the thesis depict a potential future evolution of the fishing sector, following a trajectory that combines various sustainability components. At the societal level, Chapter I provides valuable insights into the importance of using the resources available to Fisheries Local Action Groups for activities that connect the fishing sector with other local actors of the Blue Economy. This should foster the involvement of numerous stakeholders (e.g. providers of touristic services, cultural operators, environmental associations) in the decision-making process related to the directions proposed in the development strategies formulated by FLAGs.

Following these considerations, Chapter II highlights how the cultural and recreational heritage of small-scale fisheries can be a valuable asset for the development of a local economy that is increasingly less dependent on the intensive exploitation of marine resources. While maintaining a cautious approach to prevent the transformation of fishing activities into a mere touristic attraction, it is discussed how the sector can be supported in the transition towards a multifunctional economy. It has been verified, in the context of a broad European sample, that the disappearance of artisanal fisheries would have serious negative implications for collective welfare. The hypothetical consequences have been empirically evaluated using the travel cost method, providing support to policymakers envisioning financial incentives during the transition process.

Given the complexity of foreseeing such a radical transformation for the entire sector, at least in the immediate future, Chapters III and IV aim to explore innovative solutions to reduce pressure on fish stocks without necessarily compromising the profitability of fishing activities. These chapters highlight how a more flexible approach to the management of marine resources, going beyond the current input-based regulations, can ensure a more desirable alignment of environmental and economic sustainability. In addition to the originality of the methodological approaches proposed in these chapters (replicable in other contexts, even outside the beam trawl fishery of Chioggia), another contribution lies the characterization of the variability associated with both the fleet's performance (in terms of production efficiency and fishing strategies) and the price trends of various fish species. The results allow industry operators to optimize their strategies accordingly- based on the necessary inputs to reach target species in fishing zones, stock availability, and market price forecasts. In the case of fisheries characterized by a few active vessels (such as the beam trawl fishery in Chioggia), this would enable fishers to access precious scientific evidence to collaboratively decide how to achieve the common goal of generating a sufficient quantity of landings without causing a decline in prices. It is suggested that the entire process should also involve research members dealing with fisheries at the biological and ecological levels, aspects not considered in this thesis but crucial to contain the negative environmental externalities of fishing activities.

In summary, this thesis provides a holistic perspective on fisheries economics, acknowledging that the sector is not just about catching fish and making profits. It encompasses a wide array of economic, social, and environmental implications that go far beyond food provisioning, each of which must be addressed to create a thriving and sustainable fishing industry. The insights gained from this research can inform policy decisions, guide fisheries management, and shape the development strategies adopted by coastal communities.

By embracing both market and non-market value approaches and bridging the gap between environmental and economic analysis, this thesis contributes to the study of natural resource management. It highlights the importance of recognizing and quantifying the full spectrum of values that fisheries generate while simultaneously emphasizing the need for efficient, sustainable resource management. Ultimately, the goal is to ensure the long-term viability of marine resources and enhance the socio-economic condition of European coastal communities, especially in the multifaceted context of Mediterranean fisheries.