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Economic structure of fishing activity: An analysis of mackerel fishery management in the Basque Country

Javier García-Enríquez[a], Arantza Murillas-Maza[b] and Josu Arteche[a]

ABSTRACT: This paper analyses the activity of the Basque fleet during the mackerel fishing season and presents an economic analysis of the equilibrium of this fishery. It seeks to determine whether its economic structure represents an internal factor explaining the fishermen's behaviour. The inverse demand function and the average cost function are therefore estimated. Moreover, the analysis conducted here also takes into account the institutional dimension by factoring in current fishery regulation measures. Conclusions are drawn as to whether the incentives provided by the management measures and the strategy of fishermen are optimal on the basis of the estimated economic functions.

KEYWORDS: Cost structure, economic equilibrium, fishery, inverse demand function, mackerel.

JEL classification: Q21, Q22.

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Estructura económica de la actividad pesquera: un análisis de la gestión de la pesquería del verdel en el País Vasco

RESUMEN: Este trabajo analiza la actividad de la flota vasca durante la costera del verdel y presenta un análisis económico del equilibrio de esta pesquería. Se pretende determinar si su estructura económica representa un factor interno que explica el comportamiento de los pescadores. Así, se estiman la función inversa de demanda y la función de costes medios. Además, el análisis también considera la dimensión institucional, incorporando las actuales medidas de regulación de la pesquería. Se concluye analizando si los incentivos generados por las medidas de gestión y la estrategia de los pescadores son óptimos en base a las funciones económicas estimadas.

PALABRAS CLAVE: Estructura de costes, equilibrio económico, función inversa de demanda, pesquería, verdel.

Clasificación JEL: Q21, Q22.

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[a] Dpto. Economía Aplicada III (Econometría y Estadística), University of the Basque Country UPV/EHU.

[b] AZTI. Unidad de Investigación Marina.

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Corresponding author: Javier García-Enríquez. E-mail: javier.garcia@ehu.eus.

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1. Introduction

European fisheries have battled for many years against poor profitability due to the low ex-vessel prices reached at markets, among other reasons. Thus, considering the current low prices and high fuel costs, catching as much as possible represents the optimal way to increase economic profits at reasonable discount rates from the fishermen's perspective in many fisheries. This has led the Basque North East Atlantic Mackerel (NEAM) fleet[1], as is the case with other European fleets, to fish in some years more than the Total Allowable Catch (TAC) set by the authorities for this stock. In fact, although the NEAM fishery is subject to regulation (TAC, daily limits, etc.), fishermen act by maximising their individual revenues without taking into account issues such as the market, the situation of the stock or the performance of the fleet as a whole, i.e. they act as if access were unrestricted. Indeed, the structure of the demand and cost functions could well be causing the "race" by fishermen to increase their catches. This paper therefore focuses on estimating the demand and cost functions for NEAM Basque fishery to check whether the economic structure per se represents an internal factor explaining the fishermen's behaviour and, in particular, the traditional "race for the resource". Moreover, this paper analyses the degree of success of the implemented management measures and how it is affected by the economic structure, among other factors.

This paper sets out to analyse the economic situation of the Basque fleet engaged in the fishing season for mackerel (this season is called "costera") by examining the static equilibrium of the fishery, based on estimations of the demand and cost functions. It seeks to provide detailed knowledge of the key factors that condition the ex-vessel price of the stock analysed, and of the production structure and fleet costs. To that end, the first step is to identify and estimate the demand function of the market for initial sales. Given the rigidity that characterises the market supply of perishable products, the focus here is on the inverse demand function. The inverse demand function for this market is estimated and an analysis is then run to determine whether the strategy conventionally used by fishermen of maximising revenue via catches can be justified in terms of economic efficiency. An analysis of whether the regulation measures introduced by the Spanish authorities in recent years can help to increase profitability through higher prices is also conducted. We then empirically define and estimate the average cost curve associated with the mackerel fishery and use the results to learn, among other things, the gap between mackerel prices (expressed via inverse demand) and the operating costs associated with the fishing season. Finally, the estimated curves are used to calculate and analyse the economic equilibrium of the fishery.

This mackerel fishery has been selected as the case study for two main reasons. First, as the profitability of this fleet is one of the main concerns for the fishing sector itself and for the regional, state and European administrations. As a consequence, policy makers have introduced new regulations to manage this fishery in recent years:

[1] The Basque fleet consists of all vessels whose home port is located in the Basque Country (North of Spain).

A technological allocation criteria in early 2010; individual landing limits from 2009 to 2013; and finally individual quotas in 2014 (a detailed description of these regulations is introduced in Section 2). Second, as it is one of the most important fisheries for the Basque inshore fleet and also of great economic and social importance at international level (particularly for the countries on the Atlantic Arc, i.e. Spain, France and Portugal). The mackerel stock is managed annually via area-based TACs. The International Council for the Exploration of the Sea (ICES) provides advice on the admissible exploitation of the stock throughout its distribution as a whole, but that advice is transferred to two TACs: The Northern area (IIa, IIIa,b,d, IV, Vb, VI, VII, VIIIa,b,d,e, XII, XIV in ICES nomenclature) and the Southern area (which includes areas VIIIc & IXa in the ICES nomenclature). The most important stock for the Spanish fleet (and hence for the Basque fleet) is precisely that allocated to it in the South area, where they obtain over 90 % of their total catch. Spain holds 82 % of the total TAC for the South area, with the rest being allocated to Portugal and, to a much lesser extent, to France. Mackerel catches in the Basque Country accounts for between 36 % and 48 % of the total volume of catches of all species by the Basque inshore fleet between 2001 and 2008 years (Section 2 provides detailed information).

In any fishery, management must deal with economic, biological, social and even political objectives. This paper focuses on economic objectives, but also takes into account the biological sustainability targets set by the administration through the establishment of various regulatory measures. For instance, this stock is currently subject to a long-term management plan, and scientists recommend that fishing efforts and catches should be tailored to that plan. This consideration prevails over other criteria such as Maximum Sustainable Yield (MSY)[2] and the Precautionary Approach (PA)[3] (ICES, 2010), so the long-term management plan is considered to be the benchmark for the analyses conducted here.

The paper is structured as follows: Section 2 presents the case study analysed. Section 3 devotes to the empirical specification and estimation of the demand and cost functions and describes the results obtained from it. Section 4 provides a discussion of the main results. Section 5 concludes.

2. Case Study: Mackerel and its Current Management

2.1. The Mackerel Stock and its Management under TACs

Mackerel (*Scomber scombrus*) is a scombrid species found in the Mediterranean and the Atlantic. As pointed out above the ICES provides advice on permissible exploitation for the NEAM distribution area as a whole, and that advice is the basis for two TACs: One for the North area and the other for the South.

[2] MSY is the largest average catch or yield that can continuously be taken from a stock under existing environmental condition. ICES Glossary (http://www.ices.dk/pages/Glossary.aspx).

[3] Threshold on exploitation (catch, mortality, effort) consistent with a management strategy or international agreement (e.g. exploitation boundary consistent with precautionary approach). ICES Glossary (http://www.ices.dk/pages/Glossary.aspx).

TABLE 1

Catches & TACs (in thousands of tonnes) by the international, Spanish and Basque mackerel fleets*

Year	TAC (international)[a]	Catches (international)	TAC (South)	Catches in south area VIIIc & IXa (Spain + Portugal + France)	Catches (total of Spain)	Catches (only Basque Country)	Catches % (Basque/ Spain)
1989	532	590	36.6	18.3	16.6	5.9	36
1990	562	628	36.6	21.3	17.9	8	45
1991	612	668	36.6	20.8	22	11	50
1992	707	760	36.6	18	17.2	9	52
1993	767	825	36.6	19.7	20.9	11	53
1994	837	821	36.6	25	27.1	13.5	50
1995	645	756	36.6	27.5	29.2	14.1	48
1996	452	564	30	34.1	33.4	15.6	47
1997	470	570	35	40.7	46.5	24.1	52
1998	549	667	35	44.2	44.6	15.8	35
1999	562	640	35	43.8	45.9	22.2	48
2000	612	739	39.2	36.1	38.3	18.2	48
2001	670	737	40.2	43.2	44.1	23.3	53
2002	683	773	41.1	49.6	50.1	18.6	37
2003	583	670	35	26	23.8	6.7	28
2004	532	650	32.3	34.8	34.5	15.5	45
2005	422	543	24.9	49.6	52.8	23.9	45
2006	444	473	26.2	52.8	54.1	18.1	33
2007	502	579	29.6	62.8	62.9	24.5	39
2008	458	611	27	59.9	64.6	29.1	45
2009	605[b]	735	35.8	107.7	114.1	49	43
2010	885[c]	869	33.9	55.1	52.7	19	36
2011	959[c]	939	37.1	19.7	18.7	8	43
2012	927[c]	893	36.7	20.1	19.4	12	62
2013	906[c]	932	31.2	16.7	16.4	6	37
2014	1,396[c]	1,394	56.6	38.4	29.0	11	38

[a] All areas except some captures in international waters in sub-area II.
[b] It does not include the unilateral Norway/Faroe Islands TAC first declared in 2009, nor the Iceland quota.
[c] No internationally agreed quotas. Values presented are the sum of unilateral quotas.

Source: Own elaboration based on data from ICES (ICES, 2012; 2015) and the AZTI fishery database.

Given its economic and social importance at international level, this mackerel fishery is currently one of the most highly valued in the European Union (EU). Table 1 shows the main variables in the international fishery. Annual catches of the species from 1989 to 2014 averaged 732,000 tonnes, though with considerable variation from one year to another. A breakdown by countries shows that in recent years the fleets of Norway and the UK have made the largest catches (25 % of the total), though those of Denmark, Ireland, the Netherlands, Russia and Spain have also taken significant quantities (between 5 and 10 % of the total).

Table 1 shows the total catches (for all areas) by the Spanish fleet, where the quantity corresponding specifically to the Basque vessels is detailed in a different column. In spite of the fact that this stock has not been at its best in recent years, the Basque and the Spanish fleets have, in some years, landed catches far in excess of the quota allocated to them under the TAC, as can be seen in Table 1. Indeed, in some recent years Spain has landed twice as much as its allocated TAC (three times as much in 2009). In 2008 and 2009, the catches landed by the Basque fleet alone amounted to more than the TAC for the whole of Spain. Fishing activities in Basque ports accounted for 44 % of all the catches landed by the Spanish fleet between 1989 and 2014, making the Basque fleet the largest mackerel fleet fishing from home ports in Spain.

2.2. Distribution of the quota by gear and semester

A Spanish national regulation was implemented in 2010 with the aim of distributing the Spanish catch quota by gear, with the quota being 30.5 % for trawlers, 27.7 % for purse seiners and 34.6 % for artisanal fisheries. In all cases, 7 % of the catches should be kept for the second half of the year.

The basic idea is to prevent particular types of high-performance fishing gear from constraining the fishing possibilities open to other gears and hogging the Spanish quota. This gives each gear at least the possibility of catching the percentage allocated to it, but it does not prevent interaction on the market between catches landed with different types of gear.

2.3. Daily limits

In addition to the limits set via TACs, quotas and shares allocated to each gear, there are also daily limits on the amount of fish that can be landed. Such limits must be seen as ways of preventing the market from being flooded on a particular day, thus enabling higher overall prices to be assured and preventing low-capacity gears from having their prices undercut by large quantities landed by vessels using high-capacity gears. Daily limits on catches were set in 2008 (second semester) and 2009 (Orden ARM/2091/2008)[4]. These regulations were overturned for the 2010 fishing season by Orden ARM 271/2010 and Orden ARM/1054/2010, which regulated stocks more explicitly. Finally, in 2011 Orden ARM/3315/2010 introduced an additional regulation allocating a new daily limit per vessel, by European mandate[5].

[4] Catches of 20,000 kg/vessel for otter trawls, 30,000 kg/vessel for pair trawls, 1500 kg/crewman for purse seiners and 1000 kg/crewman for other gears (gillnets, hand lines and long lines).

[5] A quota of 8,000 kg/vessel for purse seiners and bottom trawlers and 2,300 kg/vessel for the artisanal category known as "artes menores". This category, that grouped all the boats using artisanal fishing methods, restricted the membership to this group in relation with a maximum total length of 18 meters and a horse power maximum of 250 HP.

Interviews were organised with local fishermen representatives, while focus groups[6] were organised with both local fishermen and local scientists. Other management measures are not considered for this fishery and, in fact, in the opinion of local fishermen (based on these interviews and focus groups), daily limits are an appropriate measure because this measure allows for a simplification of the daily fishing work, although they think the main problem is based on the previously established low TAC from which the daily limits are derived. Fishermen consider that the TAC should be higher based on their empirical evidence.

2.4. Mackerel Fishing by the Basque Fleet

In the Basque Country, mackerel is caught mainly by the inshore fleet, especially by hand lines and purse seiners. Much smaller amounts of mackerel are also landed by vessels that use gillnets and bottom-set long-lines. Line-fishing and purse-seine vessels based in the Basque Country account for between 90 % and 95 % of the mackerel landed at Basque ports (the rest is landed by vessels based mainly at ports in Cantabria, Asturias and Galicia). Catches by vessels using bottom trawl nets have increased by more than 200 % since the beginning of the last decade. Up to 2001 these vessels only occasionally landed more than 6000 tonnes of mackerel, compared to the average figures of 20,000 tonnes for artisanal vessels and 16,000 for purse seiners. From 2002 onwards the amounts caught by each type of gear began to converge.

Hand-line and purse-seine mackerel fishing vessels are extremely important in inshore fishing by the Basque fleet as a whole. Mackerel is the main target species in terms of landings in the Basque Country (with all types of gear), accounting for between 36 % and 48 % of the total volume of catches of all species by the Basque inshore fleet between 2001 and 2008 (though in 2003 the figure fell to 14 % due to the temporary closure of the fishery following the sinking of the oil tanker Prestige). In terms of revenue, mackerel is the third most important, behind albacore (*Thunnus alalunga*) and anchovy (*Engraulis encrachicolus)*, accounting for around 11 % of the total revenue of the inshore fleet (just 5 % in 2003). However, the percentage of overall income accounted for by this fishery varies depending on the total activity of each vessel throughout the year (vessels change metier[7] during the year). Thus, it accounts for between 22 and 40 % of the annual earnings of Basque vessels fishing with hand lines, though the figure is higher for trolling vessels in the summer (a fishing technology that provides 40 % of all the revenue of this fleet). Furthermore, with the crisis that has hit anchovy fishing in recent years, mackerel has accounted for as much as 45 % in some years. For the live-bait and purse-seiner fleet based on the Basque Country, mackerel accounts for between 6 and 18 % of annual earnings, depending on the amount of albacore, anchovy and bluefin tuna (*Thunnus tynnus)* that they land. Finally, mackerel provides between 1 % and 15 % of the annual ear-

[6] Focus groups are widely used in the fisheries field including stakeholders (fishermen, administration, scientists...) organised by working groups.

[7] "Metier" means a group of fishing operations intended to catch similar species (or groups of species) with similar gear during the same period of the year or in the same area, characterised by similar operational models.

nings of trawl vessels, depending on how much hake (*Merluccius merluccius*) and other species they catch.

3. Model Specification and Empirical Analysis

3.1. Empirical Specification and Estimation of the Demand Function

The data used in this study are taken from the AZTI fishery database. This database introduces information from *logbooks* and *sales notes* provided by the Basque Government, which publishes information on each fish auction. Specifically, information gathered in 2007 is used. The reason why data from other years have not been considered lies partly in a lack of detailed information and partly in the fact that 2007 was the last year in which fishing was not subject to any regulations intended to affect the economic component of fisheries (see above). The database used for the study comprises 3,395 entries once the information has been processed. It thus covers 93 % of the total catches recorded in the AZTI fishery database for 2007 (22,860 t out of a total of 24,500 t). These entries represent the daily landings from each vessel, according to the size of the fish. The number of vessels taking part in this fishery during 2007 was 235, which landed the majority of their catches at six different ports: Bermeo, Donostia, Getaria, Hondarribia, Lekeitio and Ondarroa.

In this study the inverse demand function for mackerel is estimated assuming that supply is completely inelastic and does not react to price. On perishable product markets, where products cannot be stored, quantity is usually taken as given exogenously, so price is determined exclusively by demand (see for instance Huang, 1988; Barten and Bettendorf, 1989; Eales *et al*., 1997). Moreover, all the regulations and interventions on the part of the authorities (TACs, control of fishing effort, limitation on the entry of vessels, etc.) also help ensure that price is not a factor in the determination of total supply, which is determined rather by factors external to the market (Asche and Hannesson, 2002; Herrmann and Criddle, 2006). Therefore, fisheries are among the few cases in economic literature in which inverse demand functions are considered to be plausible alternatives to simultaneous supply/demand systems (Gorman, 1959).

The mackerel market is no exception to this. Daily supply is not determined by demand, and may even exceed the daily limits set by the authorities. This is because fishermen usually adopt a strategy of maximising the volume of their catches and may thus flood the daily market. Fishermen do not care about market or other type of considerations when deciding mackerel fishing strategy. This is, among other issues, due to their perception about the good biological situation of the stock, which pushes fishermen to catch as much as possible. This perception, as part of the huge expert knowledge, is gained from focus groups with fishermen. This paper has benefited from several focus groups organised according to the different technologies: Purse seiners, artisanal fleet, and offshore trawlers. Each focus group, with a mean of 15 people involved, was organised at the NUTS 2 level, that is, including two fishermen from each of the most important ports in the Basque Country.

Identifying the inverse demand function requires not just quantity to be defined but also all the other variables (shifters) that influence the price that purchasers (mostly wholesalers) are willing to pay. A number of shifters are tested, including the size of the fish, the fishing techniques, the port where catches are landed and the fishing grounds. Of these variables, the size of fish caught, the fishing techniques and the port are found to be significant and are therefore included in the specification of the function. The fishing grounds are also significant for some categories, but are closely linked to the fishing technique and therefore improve the goodness of fit only marginally.

The fishing technique affects the freshness and quality of landings and, to a lesser extent, the channels through which mackerel is marketed. The main technologies used to catch the species are hand lines, purse seiners, gillnets, trawls and coastal trawls. When examining the differences, hand lines are taken as the baseline and the following dummy variable is considered:

$$h_i = \begin{Bmatrix} 1 & \text{if observation } i \text{ belongs to fishing technique } h \\ 0 & \text{otherwise} \end{Bmatrix},$$

where h = *PS, Gi, Tr, CTr* represents the purse seiners, gillnets, trawls and coastal trawls technologies respectively.

Appreciable differences in price are observed depending on size (the bigger the fish, the higher the price). The effect of fish size on prices is factored in by means of a dummy variable based on classifying catches into three size groups[8]: Small mackerel, medium-sized mackerel and large mackerel. The group labelled "small mackerel" is taken as the baseline, and the following dummy variable is introduced:

$$w_i = \begin{Bmatrix} 1 & \text{if observation } i \text{ belongs to size } w \\ 0 & \text{otherwise} \end{Bmatrix},$$

where w = *Med, Lar* represents medium and large sizes, respectively.

Looking at the disaggregated data by port, some differences in prices can be observed. Thus, it seems to be interesting the introduction of a dummy variable representing the port where the fish is landed and auctioned:

$$z_i = \begin{Bmatrix} 1 & \text{if observation } i \text{ belongs to port } z \\ 0 & \text{otherwise} \end{Bmatrix},$$

[8] The AZTI fishery database records information on landings according to sizes that are based on logbooks and sales notes. An analysis to classify fish into these three categories was performed by AZTI biologists on the basis of that information.

where the port of Bermeo is taken as the baseline, and z = *Don, Get, Hon, Lek, Ond* represents the ports of Donostia, Getaria, Hondarribia, Lekeitio and Ondarroa, respectively.

All the variables, except the dummies, are expressed in logs, enabling the coefficients to be interpreted as elasticities and reducing the problems that would be caused by any potential heteroscedasticity. However, evidence of heteroscedasticity is still found in some of the models specified in this study, so an heteroscedasticity-consistent estimate of the variance and covariance matrix of the estimators of the coefficients is used to enable inferences to be drawn based on Ordinary Least Squares (OLS). Thus, regressions of the log of prices on an intercept, the log of quantities and a number of dummy variables representing the fishing techniques, fish size and port where mackerel is landed and auctioned were conducted. In order to allow for elasticities changing with the fishing technique, we also introduced the interactions between the log of quantities and the different fishing techniques. Finally, as mackerel is caught mainly during a specific period of the year referred to as the "fishing season", it seems appropriate to introduce a variable to reflect the differences in market behaviour expected during the fishing season compared with the rest of the year. This effect is factored in through the interaction between the log of quantities and the following dummy variable:

$$Seas_i = \begin{Bmatrix} 1 & \text{if observation } i \text{ is made during the fishing season} \\ 0 & \text{otherwise} \end{Bmatrix},$$

in which the fishing season is considered to last from February 1 to April 20 (AZTI fishery database)[9].

This gives rise to the following model to be estimated:

$$\begin{aligned} \ln(p_i) = {} & \beta_0 + \beta_1 \ln(q_i) + \beta_2 PS_i + \beta_3 Gi_i + \beta_4 Tr_i + \beta_5 CTr_i + \beta_6 Med_i \\ & + \beta_7 Lar_i + \beta_8 Don_i + \beta_9 Get_i + \beta_{10} Hon_i + \beta_{11} Lek_i + \beta_{12} Ond_i \\ & + \beta_{13} \ln(q_i) Seas_i + \beta_{14} \ln(q_i) PS_i + \beta_{15} \ln(q_i) Gi_i + \beta_{16} \ln(q_i) Tr_i \\ & + \beta_{17} \ln(q_i) CTr_i + \varepsilon_i. \end{aligned}$$

Quantities for possible substitute goods of the kind traditionally employed in studies of this type are not included here because, as per García-Enríquez (2012), mackerel has no substitutes in the market. In particular, after carrying out a fractional cointegration analysis among historical price series of mackerel and other small pelagic fishes (sardine, chub mackerel and horse mackerel), the author concludes that prices of the mackerel landed and auctioned at Basque ports are not related to the ones of the other considered species. This means, among others, that buyers at origin do not consider substitutes of this species.

[9] These dates were taken for the fishing season after careful observation of landings in 2007. Other periods were also tested, but the results did not vary.

Likewise García-Enríquez *et al*. (2014) study the horizontal relationships among the different Spanish regional markets of mackerel at origin: Basque Country, Cantabria, Asturias, Galicia and Andalusia by means of fractional cointegration techniques. The results show that the price creation process of one market does not affect the others, but they are instead linearly independent and produced at local level. Thus, geographically speaking, the existence of five independent regional mackerel markets in Spain (one for each region) can be established. On the other hand, supply usually exceeds demand in the Basque mackerel market at origin. In fact, there exists a freezer owned by the fishermen which buys the mackerel that cannot be sold in the market due to the low demand (or when the sale price is lower than a particular minimum price). Then this fish is usually exported to the East Europe markets -Romania and Bulgaria mainly- but not for direct consumption but to be processed and used in the elaboration of other goods such as flour. Due to all these reasons we decide not to consider the inclusion of imports as explanatory variable of prices.

Other variables that could be relevant in explaining price formation, such as the order in which the batches of landed mackerel are auctioned, are not included because no information on them is collected by any organisation.

Table 2 shows the main descriptive statistics for the variables price and quantity, which can be helpful to understand the model. The statistics are calculated at a disaggregated level, considering all the different technique/size and port/size combinations. The first line of each cell represents the main statistics (mean, median and standard deviation) for price and the second one (between round brackets) the same for quantity. The number of observations (first column of each cell) is obviously common for both price and quantity variables. In general terms it is observed that average price and quantity increases as fish size does, although there are exceptions due to some large standard deviations, so the medians are also of interest. Looking at the total figures by technique, purse seiners are the ones with the largest average landings and the smallest prices, whereas the lowest average quantity is reached by gillnets and biggest average prices by coastal trawls. Regarding ports, the interest lies especially on the differences in total average price and quantity. As it can be observed there are no differences in average prices among Getaria, Hondarribia and Lekeitio, being Donostia, Ondarroa and Bermeo the ports with the highest prices. The order in terms of average landings is completely different, with Donostia being the smallest and Getaria the largest.

Table 3 shows the results for the estimation of the proposed model. The fit shows that all variables are individually significant except for the ports of Donostia and Ondarroa. However, it was decided not to exclude them so as to give a complete picture of all the different ports. Evidence against the homoscedasticity hypothesis was observed (typical testing procedures such as White and Breusch-Pagan tests reject the null hypothesis of homoscedasticity with p-values < 0.0001), so a heteroscedasticity robust estimation of the standard deviations of the OLS estimator was used. As far as goodness of fit is concerned, the model explains 60.75 % of the total variability of the log of prices.

TABLE 2

Main descriptive statistics for price and quantity

		Small				Medium				Large				Total			
		N.º obs.	**Mean**	**Median**	**Std. Dev.**	**N.º obs.**	**Mean**	**Median**	**Std. Dev.**	**N.º obs.**	**Mean**	**Median**	**Std. Dev.**	**N.º obs.**	**Mean**	**Median**	**Std. Dev.**
Fishing technique	Hand lines	10	0.28	0.25	0.10	64	0.30	0.25	0.14	2137	0.54	0.43	0.32	2211	0.53	0.43	0.52
			(519)	(264)	(586)		(1,962)	(1,867)	(1,581)		(3,806)	(3,000)	(3,276)		(3,738)	(2,926)	(3,254)
	Purse seiners	36	0.38	0.23	0.42	20	0.27	0.25	0.07	834	0.42	0.30	0.43	890	0.41	0.29	0.42
			(692)	(298)	(953)		(10,120)	(5,463)	(11,046)		(15,934)	(9,700)	(19,145)		(15,187)	(8,770)	(18,860)
	Gillnets	0	-	-	-	11	0.54	0.40	0.31	47	1.47	1.40	0.71	58	1.29	1.13	0.75
			-	-	-		(58)	(8)	(99)		(128)	(7)	(307)		(115)	(7)	(280)
	Trawls	1	0.18	0.18	-	2	1.30	1.30	0.06	24	0.97	0.89	0.63	27	0.96	0.98	0.62
			(110)	(110)	-		(46)	(46)	(31)		(2,253)	(473)	(4,520)		(2,010)	(313)	(4,308)
	Coastal trawls	3	0.47	0.35	0.29	118	1.48	1.53	0.78	88	1.34	1.03	0.95	209	1.41	1.41	0.86
			(38)	(36)	(33)		(6,244)	(474)	(11,634)		(3,179)	(372)	(5,353)		(4,864)	(432)	(9,526)
Port	Bermeo	0	-	-	-	0	-	-	-	1739	0.53	0.44	0.33	1739	0.55	0.44	0.33
			-	-	-		-	-	-		(3,855)	(3,245)	(3,238)		(3,855)	(3,245)	(3,238)
	Donos-tia	0	-	-	-	0	-	-	-	75	1.06	0.82	0.78	75	1.06	0.82	0.78
			-	-	-		-	-	-		(2,696)	(56)	(6,764)		(2,696)	(56)	(6,764)
	Getaria	0	-	-	-	4	0.27	0.22	0.13	391	0.33	0.28	0.16	395	0.33	0.28	0.16
			-	-	-		(3,150)	(2,167)	(3,763)		(20,032)	(12,582)	(23,032)		(19,862)	(12,393)	(22,979)
	Honda-rribia	1	0.51	0.51	-	24	0.30	0.22	0.21	221	0.33	0.30	0.19	246	0.33	0.30	0.19
			(80)	(80)	-		(1,005)	(309)	(3,175)		(12,424)	(8,740)	(12,298)		(11,260)	(7,108)	(12,198)
	Lekeitio	1	0.25	0.25	-	67	0.34	0.28	0.17	125	0.33	0.28	0.10	193	0.33	0.28	0.13
			(113)	(113)	-		(4,356)	(2,739)	(6,920)		(3,767)	(1,790)	(5,755)		(3,952)	(1,987)	(6,165)
	Onda-rroa	48	0.36	0.25	0.37	120	0.57	0.41	0.48	579	0.73	0.43	0.68	747	0.83	0.45	0.74
			(627)	(264)	(874)		(6,141)	(453)	(11,564)		(6,577)	(2,272)	(10,592)		(6,124)	(1,534)	(10,508)

Note: The top number in each cell corresponds to price (euros/kg) and the bottom number, between round brackets, to quantity (kg).

Source: Own elaboration based on data from ICES (ICES, 2012; 2015) and the AZTI fishery database.

TABLE 3

OLS estimate of inverse demand function

Variable	Parameter Estimate	Standard deviation	p-value
Constant	-0.0531	0.1114	0.6338
ln (q_i)	-0.1397	0.0109	< 0.0001
PS_i	-0.8777	0.1008	< 0.0001
Gi_i	-0.6434	0.1617	< 0.0001
Tr_i	-1.1346	0.2695	< 0.0001
CTr_i	-0.3601	0.1316	0.0062
Med_i	0.9280	0.1037	<0.0001
Lar_i	1.1173	0.0934	< 0.0001
Don_i	-0.0675	0.0697	0.33276
Get_i	-0.1446	0.0300	< 0.0001
Hon_i	-0.2500	0.0354	< 0.0001
Lek_i	-0.4186	0.0305	< 0.0001
Ond_i	-0.0071	0.0230	0.7562
ln (q_i) $Seas_i$	-0.0967	0.0050	< 0.0001
ln (q_i) PS_i	0.0986	0.0112	< 0.0001
ln (q_i) Gi_i	0.1027	0.0363	0.0047
ln (q_i) Tr_i	0.1809	0.0448	< 0.0001
ln (q_i) CTr_i	0.1094	0.0172	< 0.0001

Source: Own elaboration.

An interpretation of the model follows, with explanations of how expected prices vary in reaction to changes in the different variables:

Quantity (elasticity of demand – ε_D –)[10]. The estimated elasticity ($\hat{\varepsilon}_D$) depends on the fishing technique and the season as follows:

$$\hat{\varepsilon}_D = -0.1397 - 0.0967 Seas_i + 0.0986 PS_i + 0.1027 Gi_i + 0.1809 Tr_i + 0.1094 CTr_i \ .$$

The elasticities therefore vary in line with the fishing technique and the season. For instance Table 4 shows the different elasticities during the fishing season together with the p-value associated with the tests of significance.

[10] Note that since the inverse function is used instead of the demand function, the elasticities are interpreted as responses on the part of the prices that purchasers are willing to pay in reaction to changes in the quantities demanded.

TABLE 4

Estimated elasticities ($\hat{\varepsilon}_D$) per fishing technique during the fishing season

	$\hat{\varepsilon}_D$	*p*-value
Hand lines	-0.1397 - 0.0967 = -0.2364	< 0.0001
Purse seiners	-0.1397 - 0.0967 + 0.0980 = -0.1378	< 0.0001
Gillnets	-0.1397 - 0.0967 + 0.1027 = -0.1337	0.0002
Trawlers	-0.1397 - 0.0967 + 0.1809 = -0.0555	0.2065
Coastal trawlers	-0.1397 - 0.0967 + 0.1094 = -0.1270	< 0.0001

Source: Own elaboration.

Taking into account the results of the tests of significance at 5 % for the different price elasticities, it can be asserted that during the fishing season an increase of 1 % in the quantity demanded results in a fall in price for all techniques except trawlers, for which prices are unaffected by the quantity of fish landed. Specifically, there are falls of 0.24 % for hand lines, 0.14 % for purse seiners, 0.13 % for gillnets and 0.13% for coastal trawlers. However the number of observations for gillnets and trawlers is very low, so the results for these fishing techniques should be regarded with caution.

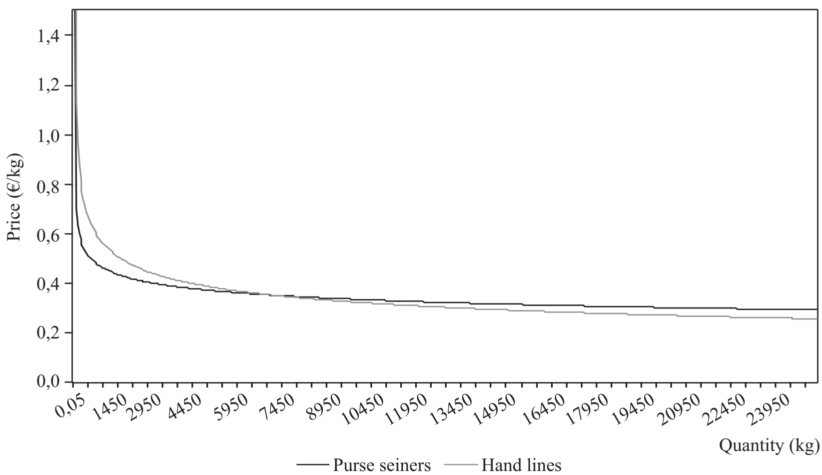
Fishing season. The fishing season effect depends on quantity and takes the form of a price drop during the fishing season of 0.10 % for each percentage point of increase in the quantity demanded. The fact that prices are lower during the fishing season than during the off-season for the same quantities is probably due to the fact that the possibility of purchasing elsewhere (i.e. changing sellers) is far greater during the fishing season. Moreover, purchasers know that there will be mackerel available on the market during the fishing season, so not purchasing on a particular day poses no problems because they know that they will be able to purchase again very shortly.

Fishing technique. The effect of the fishing techniques depends on the quantity due to the interactions included in the model. Thus, taking the price for hand lines as the baseline, expected prices for purse seiners, gillnets, trawlers and coastal trawlers are: $(-0.88 + 0.10 \ln q_i) \times 100$ %, $(-0.64 + 0.10 \ln q_i) \times 100$ %, $(-1.13 + 0.18 \ln q_i) \times 100$ % and $(-0.36 + 0.11 \ln q_i) \times 100$ % lower. As it can be observed, there are two effects to be considered here: The first term of each expression is always negative and does not depend on the quantity; the second term, however, is always positive and increases with quantity. Thus, although hand lines obtain the highest price in general, this must not be the case for large quantities. The effects on the demand curve of the two main fishing techniques during the fishing season, which is the most significant period, are shown below (Graph 1). The graph shows the data for the "large mackerel" size, the most usual one, and the port of Bermeo, but its structure would be similar for other size groups and ports in view of the constant ratio of elasticity to size and ports. As it can be observed, the price for fish caught by purse seines only exceeds that of catches made with lines when the batch size is greater than 6,600 kg.

Taking into account that more than the 80 % of the batches landed by lines are smaller in size than 6,600 kg, it can be concluded that the price paid for fish caught with lines is usually higher than for catches made with purse seiners. This is probably because purchasers perceive line-caught fish as being of higher quality due to the way in which the fish is treated during the fishing operations themselves and when being handled on-board vessels.

GRAPH 1

Estimated demand functions for hand lines and purse seiners during the fishing season



Source: Own elaboration.

Size. The expected prices of “medium-sized” and “large” mackerel are 93 % and 112 % higher respectively than the expected price of the “small” group. These figures indicate that the larger the fish is, the higher the prices that purchasers are willing to pay.

Port. First, the expected prices at ports of Getaria, Hondarribia and Lekeitio are 14 % lower, 25 % lower and 42 % lower, respectively, than the expected price at Bermeo port. Second, looking at the *p*-values associated with the ports of Donostia and Ondarroa, there is no evidence of differences between the expected prices at these ports and at Bermeo port.

3.1.1. Effects of Management on the Fishery

This subsection uses the estimated demand function to analyse the effects of introducing a daily limit in terms of fleet profitability. From 2008 to 2010 a daily limit per fisherman was set on catches with the intention of preventing the daily market from being flooded and thus raising prices. Our objective here is to check whether that measure enables profitability to be increased on the basis of a lower volume of catches and whether it influences the daily market price. To that end, the regulations applicable in 2010 are considered.

If a similar limit to that applied in 2010 had been in force in 2007, catches would have totalled just over 18,000 tonnes, i.e. around 74 % of the volume actually landed that year[11]. Limits for hand lines and gillnets are set according to the number of fishermen –with the average figures being 7 and 4 respectively (AZTI)–. The calculations for purse seiners did not take into account the fact that the regulations allow catches to be accumulated under certain conditions[12]. A comparison between the actual catches landed in 2007 (in tonnes) and those that would have been permitted under the daily limits applicable in 2010 reveals that the quantities caught by purse seiners and hand lines with the limits would have been 39 % lower and 11 % lower, respectively. The decrease for the other fishing techniques would have been less than 4 % in all cases.

The average price of mackerel (per fishing technique and per fishing season) in 2007 (without daily limit regulation) is compared below with the average price resulting from the inverse demand function under the daily limits system. By way of example, Table 5 shows the results for the "large mackerel" size group and for the port of Bermeo. The figures obtained for other sizes and ports are qualitatively similar.

Outside the fishing season, the only variation in the price per kg is in the mackerel landed by the purse-seine fleet, where there is an increase of around one eurocent. The price of mackerel caught with other types of gear remains the same, as they are unaffected by daily limits. During the fishing season, purse-seiners and hand-lines are the most affected techniques by the daily limits system: The prices of catches made with these techniques increase between one and a half and two eurocents per kg. The price paid for mackerel caught by coastal trawlers, landings which are on average slightly greater than the maximum permitted under the daily limits, also increases, by around a third of a eurocent. Finally, there would be no changes in price for mackerel caught with trawls and gillnets, since daily limits are not exceeded in these fishing techniques. Thus, the effect on prices (and therefore on profitability) of introducing a daily limit would have been zero (or practically zero) for trawlers, coastal trawlers and gillnet vessels, and would have been very limited for purse-seiners and hand-line vessels. It is without doubt the purse-seine fleet the one that would be affected most by the daily limits system, since it catches more than its limit during and outside the

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[11] The daily quotas per fishing technique for 2010 were as follows: 18,000 kg/day for individual bottom trawls (36,000 kg/day for pair trawls); 18,000 kg/day for purse seiners with GT over 100 t; 9,000 kg/day for purse seiners with GT below 100 t (with those whose GT was less than 50 t being limited to 700 kg/day in the second half of the year); and 100 kg/fisherman/day for lines and gillnets.

[12] Should bad weather prevent vessels using this fishing technique from setting sail due to their special characteristics on certain working days within the same week, they will be allowed to add the quantities not caught to their catches on the remaining days of that week, in line with the daily quota established, but vessels with a GT of more than 100 t may in no case exceed 90,000 kg per vessel per week and those with a GT of less than 100 t may not exceed 45,000 kg per vessel per week (Orden ARM/271/2010).

fishing season. Under the daily limits system, this fleet would have had to reduce its catches by almost 40 %, which would have resulted in price increases of up to 2 or 1 eurocents per kg, depending on the time period. As an example, in Table 6 the average revenues per vessel (in euros) that purse-seiners, hand lines and coastal trawlers would have obtained in fishing season with daily limits and without them are presented. This serves to justify the strategy adopted by fishermen of catching as much as possible. Moreover, the empirical evidence shows that in those fishing seasons for which daily limits were actually imposed (2008-2010) their effect on prices was practically zero (AZTI fishery database). This provides empirical corroboration of the results of the analysis conducted here for 2007.

TABLE 5

Average daily catches (in kg) per vessel with no daily limits and with daily limits & associated prices (in euros) per fishing technique

			In fishing season		
	kg w/o limits	**€/kg w/o limits**	**kg w limits**	**€/kg w limits**	**Price increase**
Hand-lines	3,872	0.4014	3,312	0.4167	0.0153
Purse seiners	13,330	0.3199	8,514	0.3406	0.0207
Gillnets	105	0.8013	105	0.8013	0
Trawlers	1,319	0.6120	1,319	0.6120	0
Coastal trawlers	7,677	0.6357	7,350	0.6393	0.0036
			Outside fishing season		
	kg w/o limits	**€/kg w/o limits**	**kg w limits**	**€/kg w limits**	**Price increase**
Hand-lines	233	1.3591	233	1.3591	0
Purse seiners	416	0.9501	314	0.9608	0.0107
Gillnets	23	1.3561	23	1.3561	0
Trawlers	1,777	1.2704	1,769	1.2701	-0.0003
Coastal trawlers	1,343	1.6387	1,343	1.6387	0

Source: Own elaboration.

TABLE 6

Average daily revenues (in euros) per vessel with no daily limits and with daily limits per fishing technique

	Revenues w/o limits	Revenues w limits	Revenues increase
Hand-lines	1,554.27	1,380.27	-174
Purse seiners	4,264.52	2,900.22	-1,364.3
Coastal trawlers	4,880.52	4,699.15	-181.37

Source: Own elaboration.

3.2. Empirical Specification and Estimation of Cost Function

Information on the annual costs of the vessels involved in the fishing season for mackerel is obtained from numerous sources –mainly the Basque government and the fishing industry– and is available from AZTI. As pointed out before, the number of vessels taking part in this fishery during 2007 was 235. However, there is no costs information in all of them because that information is obtained by means of an annual survey that the Basque government conducts among a sample of vessels. Thus, in 2007 the number of vessels that having landed mackerel answered the survey was 74.

An analysis of the cost structure of vessels brings to light three main headings: a) personnel costs; b) fuel costs and c) other maintenance and repair costs.

The demand function estimated for 2007 uses daily data and it was therefore decided to also estimate a daily cost function for that year. However, surveys conducted to obtain cost data are made on an annual basis. Calculations are therefore required to determine what part of the total costs can be attributed to the mackerel fishing season, since most Basque vessels work in a number of different metiers during the year and therefore they also land species other than mackerel (for example the Basque artisanal fleet may land as many as 60 different species in a year).

Costs are allocated to the mackerel fishing season via the application of a number of criteria set out by Prellezo (2011). First, the different expense items (around 30) are classified as follows: (1) personnel costs associated with payments to crewmen (dependent on catches); (2) personnel costs not involving payments to crewmen (not dependent on catches); (3) variable costs; (4) fixed costs[13] and (5) fuel costs[14].

Once items have been classified the following criteria are applied:

i. For items dependent on catches (items 1 and 3) the percentage allocated to the fishing season is the percentage of total revenue from fishing accounted for by this species.
ii. For items not dependent on catches (items 2 and 4) the percentage allocated to the fishing season is the percentage of the total fishing season for the year (in months) accounted for by the fishing season for this species (in months)[15].
iii. For fuel (item 5) the allocation is based on applying criterion ii to each vessel, then the resulting figures weighted according to the percentage of total landings of all species accounted for by mackerel landings during the fishing season (February 1 - April 20).

[13] The fixed costs we refer to are of annual frequency, such as insurance premia, port fees, licenses… They are different from the variable costs because they do not depend on catches, but they also should be included in the estimation of the cost function.

[14] Prellezo (2011) includes a sixth item called “cofradía” costs, but it was decided to subsume this into “variable costs” as it depends partly on catches. “Cofradía” is the term used to refer to the fishermen organizations in the Basque Country. Fishermen must pay a cost to their “cofradía”, which depends partly on catches.

[15] The fishing season lasts 3 months (February, March and April) and a count of the number of months during that time when each vessel sets out to catch mackerel is made. The figure used is therefore 1, 2 or 3, depending on each vessel.

This provides information on total costs during the fishing season for mackerel, and breaks down that information into the three main headings indicated above: Personnel costs (the sum of items 1 and 2), fuel costs (item 5) and other maintenance and repair costs (the sum of items 3 and 4). These costs can then be divided by the fishing effort (measured here in terms of the number of tides) to obtain the daily costs associated with the mackerel fishing season[16].

A single cost equation is estimated since not enough observations are available for distinctions between techniques to be drawn (after dropping the observations of those vessels whose mackerel landings were residual the final number of observations is 58). However, the main differences in cost between techniques usually arise in the quantity of fuel consumed, and this mainly depends in turn on the size and power of each vessel. For that reason the fuel price index calculated below takes the length and power of each vessel into account.

Cost items are expressed below in line with the variables quantity, prices and the price of the different production inputs (following Bjørndal and Gordon, 2001; Nøstbakken, 2006; Lazkano, 2008 among others). In particular, the following definitions are used to obtain price and quantity indices for the three major cost headings identified above:

1) Personnel costs.

    a) Proxy for quantity: Average number of full-time crewmen.
    b) Proxy for price: Personnel cost divided by the average number of full-time fishermen, i.e. the cost of hiring one fisherman for one day during the mackerel fishing season.

2) Fuel costs.

    a) Proxy for quantity: The method proposed by Lazkano (2008) is used, i.e. $power^{0.5}\ length^{0.5}$, with power measured in horsepower and length in metres.
    b) Proxy for price: $\dfrac{spending\ on\ fuel}{Power^{0.5}\ length^{0.5}}$.

3) Other maintenance and repair costs (“other costs”).

    a) Proxy for quantity: Average daily catch during the fishing season.
    b) Proxy for price: Other costs divided by the average daily catch during the fishing season (in kg), i.e. the cost of catching one kg of mackerel in terms of “other costs”.

[16] There are only residual landings outside the fishing season. In 2007 they accounted for around 4 % of the total.

Once the production input price indices are calculated, the next step is to specify the functional form to be estimated. The form that is conventionally most widely used is the trans-logarithmic form, due to its great flexibility (see, for instance, Tran and Smith, 1983; Bjørndal and Gordon, 2001; Morgenstern *et al*., 2002; Nøstbakken, 2006 or Lazkano, 2008). Thus, the model to be estimated is the following:

$$\ln c_i = \alpha_0 + \sum_{j=1}^{3} \alpha_j \ln p_{ji} + \alpha_q \ln q_i + \frac{1}{2}\sum_{j=1}^{3}\sum_{h=1}^{3} \alpha_{jh} \ln p_{ji} \ln p_{hi} + \sum_{j=1}^{3} \alpha_{jq} \ln p_{ji} \ln q_i + \frac{1}{2}\alpha_{qq} \ln^2 q_i + \varepsilon_i, \qquad [2]$$

where, for a vessel i, c_i is the cost per kg caught, p_{1i} , p_{2i} and p_{3i} are the price indices for personnel, fuel and other maintenance and repair costs, respectively, and q_i is the average daily quantity landed.

If the underlying cost function is continuous, as per the Young Theorem[17], then it must hold that $\alpha_{jh} = \alpha_{hj} \ \forall j, h$, so the number of parameters of [2] decreases in this case from 18 to 15.

In all cases the cost function must fulfil the following properties: It must be (i) first-degree homogenous in prices; (ii) non-decreasing in input prices; (iii) concave; and (iv) continuous in prices. The case under study here uses an average cost function rather than a cost function, but a check that all these properties are fulfilled on the average cost curve guarantees that they are also fulfilled on the total cost curve.

Property (i) is usually imposed on the model by means of the following constraints:

$$\sum_{j=1}^{3} \alpha_j = 1, \quad \sum_{h=1}^{3} \alpha_{jh} = 0 \ \text{ y } \ \sum_{j=1}^{3} \alpha_{jq} = 0,$$

while fulfilment of the remaining properties is checked on the model estimated[18].

Using Shephard's lemma (Shephard, 1953) the equations for the optimal factor demand equations or factor share equations (s_1, s_2 y s_3) can be obtained from the cost function[19]:

$$s_1 = \frac{\partial \ln c_i}{\partial \ln p_1} = \alpha_1 + \alpha_{11} \ln p_{1i} + \alpha_{12} \ln p_{2i} + \alpha_{13} \ln p_{3i} + \alpha_{1q} \ln q_i, \qquad [3]$$

[17] The Young Theorem states that if a function $f(x_1, x_2, ..., x_n)$ has continuous second partial derivatives at any given point, say $(a_1, a_2, ..., a_n)$, then: $\frac{\partial f}{\partial x_i \partial x_j}(a_1, a_2, ..., a_n) = \frac{\partial f}{\partial x_j \partial x_i}(a_1, a_2, ..., a_n)$ for every $i, j = 1, 2, ..., n$.

[18] The property of continuity can be checked straightforwardly. The function in question is logarithmic, so it is known to be continuous throughout its domain, i.e. for all strictly positive prices.

[19] Shephard's lemma states that the conditional factor demand for each input factor is equal to the derivative of the cost function with respect to the factor price.

$$s_2 = \frac{\partial \ln c_i}{\partial \ln p_2} = \alpha_2 + \alpha_{22} \ln p_{2i} + \alpha_{12} \ln p_{1i} + \alpha_{23} \ln p_{3i} + \alpha_{2q} \ln q_i, \qquad [4]$$

$$s_3 = \frac{\partial \ln c_i}{\partial \ln p_3} = \alpha_3 + \alpha_{33} \ln p_{3i} + \alpha_{13} \ln p_{1i} + \alpha_{23} \ln p_{2i} + \alpha_{3q} \ln q_i. \qquad [5]$$

Given the link between the cost equation and the share equations, the disturbances in equations [2], [3], [4] and [5] can be expected to be related, so the usual practice in the relevant literature is to consider them as a system of seemingly unrelated regression equations (SURE). However, taking into account that the shares of the factors add up to one, a joint estimation of all four equations results in singularity in the joint variance and covariance matrix of the disturbances, and one of the share equations is therefore excluded from the system. The demand equation excluded here is the one for "other maintenance and repair costs", i.e. [5], though if any other had been excluded instead the results would not be altered provided that estimations are made with maximum likelihood or using iterated Feasible Generalized Least Squares (FGLS), which converges to maximum likelihood. In this study, the second option is selected and consistent estimators are obtained which are relatively more efficient than those that would be obtained from OLS estimation of a model formed solely by [2].

Table 7 shows the results for estimating equation [2], performed as described above. All the parameters estimated are found to be significant at 5 % except for the cross product of the log of quantity and the log of fuel price. And it is also worth noting that the signs of the coefficients are as predicted by economic theory. Specifically, the average costs are increasing with input prices (property (ii)), decreasing with catches up to a certain quantity and increasing thereafter. In particular, the partial derivative of $\ln c_i$ with regard to $\ln q_i$ is

$$\frac{\partial \ln c_i}{\partial \ln q_i} = -0.4368 + 0.0777 \ln q_i - 0.0933 \ln p_1 + 0.0162 \ln p_2 + 0.1095 \ln p_3.$$

However, the decreasing section dominates because a substantial proportion of the total costs are fixed costs. This prevents the estimated average cost function from taking a clear U-shape.

TABLE 7

Estimate of average cost function

Variable	Parameter estimate	Standard deviation	*p*-value
Constant	1.2829	0.4038	0.0028
$\ln P_{1i}$	0.3218	0.0702	< 0.0001
$\ln P_{2i}$	0.3570	0.0826	< 0.0001
$\ln P_{3i}$	0.3212	0.0616	< 0.0001
$\ln q_i$	-0.4369	0.1071	0.0002
$\ln P_{1i} \ln P_{1i}$	0.1714	0.0113	< 0.0001
$\ln P_{1i} \ln P_{2i}$	-0.0589	0.0102	< 0.0001
$\ln P_{1i} \ln P_{3i}$	-0.1125	0.0074	< 0.0001
$\ln P_{2i} \ln P_{2i}$	0.1091	0.0125	< 0.0001
$\ln P_{2i} \ln P_{3i}$	-0.0502	0.0073	< 0.0001
$\ln P_{3i} \ln P_{3i}$	0.1627	0.0079	< 0.0001
$\ln P_{1i} \ln q_i$	-0.0933	0.0094	< 0.0001
$\ln P_{2i} \ln q_i$	-0.0162	0.0105	0.1311
$\ln P_{3i} \ln q_i$	0.1095	0.0095	< 0.0001
$\ln^2 q_i$	0.0778	0.0156	< 0.0001

Source: Own elaboration.

For the average cost function to be concave in prices (property (iii)) it suffices for the Hessian matrix (H) to be negative semi-definite. Following Diewert and Wales (1987), this matrix is calculated. Since the dispersion relative to the arithmetic mean of prices is wide, *H* is evaluated at the median values[20]. The relevant operations result in singular values of H of -0.1381, -0.0019 and 0.0000, so the matrix can be considered as negative semi-definite and the concavity of the cost function is assured.

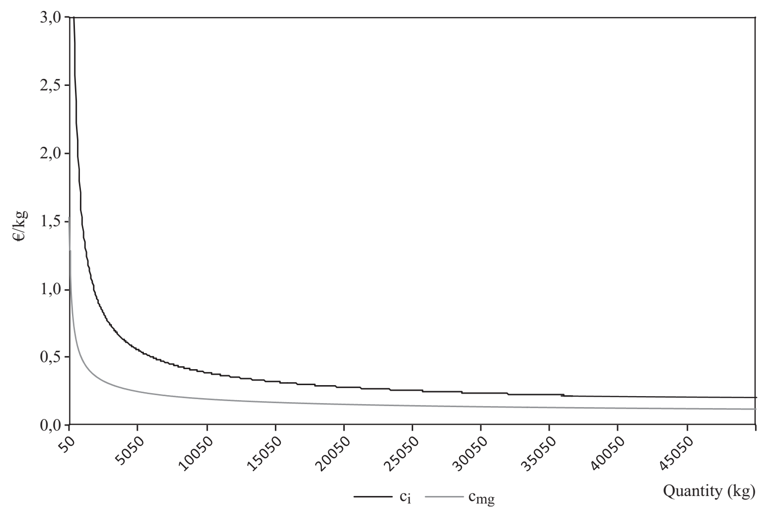
Graph 2 shows the average and marginal cost functions estimated for the same range of quantities used for the demand function (between 0 and 50,000 kg) and where prices have been evaluated at their respective median values. As can be seen, the function is decreasing for this range of catches. As a result, the strategy followed by fishermen of maximising revenue through catches also maximises profit. The efficient level of production, defined as that which minimises average production costs, is attained with landings of 5,368 t. For that volume of landings, the average cost should be equal to the marginal cost. It seems clear that the fishery is operating within a range of catches which is always below the effective production level defined. This means that the fishing operations of each vessel are located to the left of the minimum average cost. Thus, fishing operations are carried out in an area where the average and marginal cost curves are decreasing, with the marginal cost being lower

[20] The geometric mean was also tried, not affecting the conclusions.

than the average cost. This strongly conditions the strategies that can be followed to improve profitability, because economic equilibrium is unattainable, regardless of the relationship between the demand and average cost curves (which is analysed below). It is therefore not possible to estimate a reference price relative to efficient, environmentally sustainable production.

GRAPH 2

Estimated average cost (c_i) and marginal cost (c_{mg}) functions



Source: Own elaboration.

3.3. Economic Equilibrium

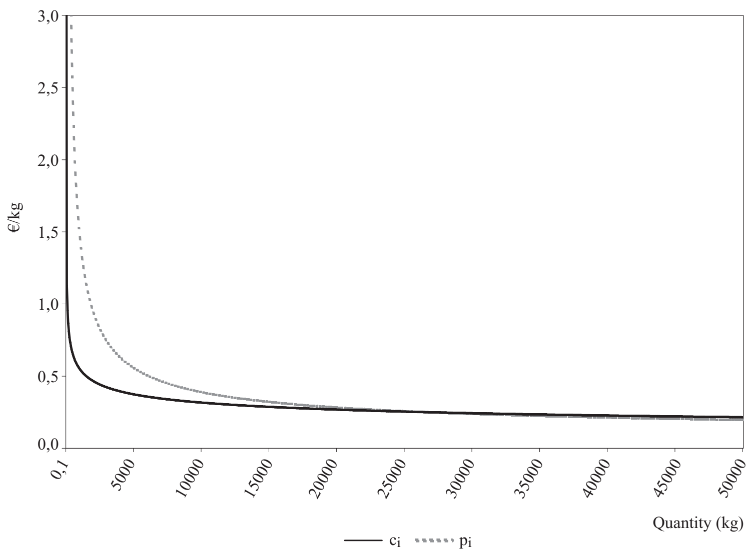
This subsection analyses the economic equilibrium of activity based on the demand and cost curves estimated. It incorporates the concept of income, defined here on the basis of the profit obtained from the operation of each vessel (Price × Catches - Average Cost × Catches). The analysis takes into account the biological reference points derived from the biological model estimated by the ICES Working Group on Widely Distributed Stocks (WGWIDE).

Although access to the mackerel fishery is regulated, fishermen behave individually, maximising their revenue without considering the situation of the stock or the performance of the fleet as a whole, i.e. as if there were free access. Considering a bio-economic model, Holland (2008) stresses that a profit maximising strategy may be more of a collective behaviour pattern (fishermen form part of a group) than an individual one.

In the case of the mackerel fishery, this behaviour could be explained in terms of the result set out above: Landings are located to the left of the minimum average cost, which makes not possible to reach an economic equilibrium. The strategy in the specific case of purse-seine vessels is also implemented because of their high fishing capacity. For hand-line vessels, which can obtain better prices and are therefore able to manage catches more suitably, the strategy adopted is ultimately conditioned by what purse-seine vessels do, so such vessels also find it optimal to maximise catches.

GRAPH 3

Average cost function (c_i) vs demand function (p_i) for hand lines

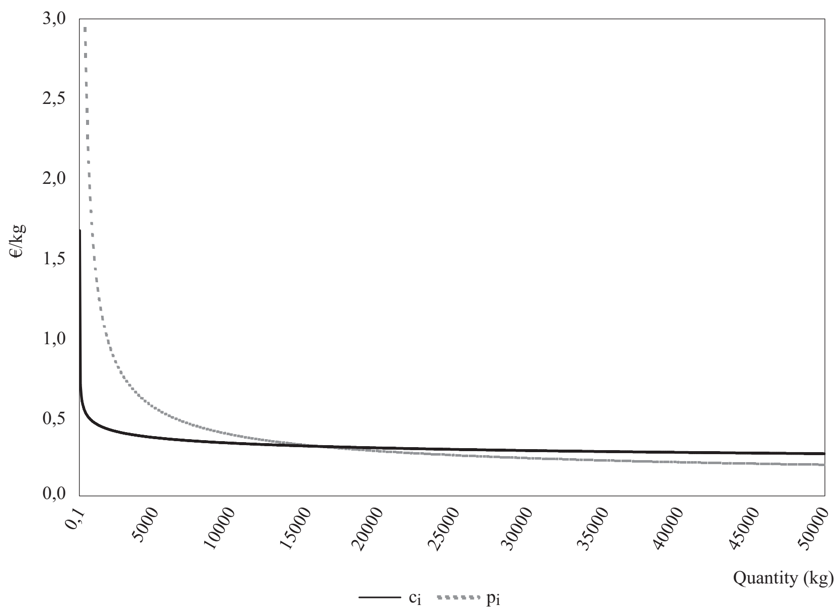


Source: Own elaboration.

Although there is no question of attaining an economically efficient equilibrium or, therefore, a socially efficient equilibrium, it is still useful to analyse the gap between prices and costs at least to learn how profitable this fishery is for the particular analysed situation. Thus, Graph 3 and Graph 4 show examples of the estimated average cost function (C_i) and the estimated inverse demand function (P_i) during the fishing season for the most widely used fishing techniques, i.e. hand lines and purse seiners, respectively. It can be seen that the cost of mackerel per kg is higher than the price per kg paid to fishermen for the lowest quantities. However, the gap narrows as the quantities landed increase, and is positive when catches are above 16,000 kg for purse seiners and above 26,600 kg for hand lines. Regarding hand lines technique, it should be taken into account that in 2007 only one vessel landed more than 26,600 kg in one day, so the economic equilibrium is associated with a level of exploitation of stocks that is certainly not sustainable. Meanwhile, the quantity for which the average cost and demand curves intersect in the case of purse seiners can be considered plausible, even though it is large. For gillnets, costs begin to fall below the level of prices when daily landings exceed around 8,000 kg. However, in 2007 no gillnet vessel landed more than 2,000 kg. For trawlers the intersection of the demand and cost functions is located at around 5,000 kg, and it is around 3,200 kg for coastal trawlers, and so it seems that these techniques are able to work this fishery more profitably than the others.

GRAPH 4

Average cost function (c_i) vs demand function (p_i) for purse seiners



Source: Own elaboration.

4. Discussion

The structure of the demand and cost functions plays an important role when explaining the "race" of fishermen to increase catches. They are willing to continue catching as much fish as possible even at the risk of overexploiting the species. Indeed, this situation has led the Basque fleet alone to land catches in excess of the TAC allocated to the whole of Spain. However, this attitude is not specific to the Basque mackerel fishing fleet: The European Commission itself has raised the issue on more than one occasion. Moreover, it must be stressed that it is the market itself that forces fishermen to resort to bigger catches to make their operations profitable. Empirical evidence from the mackerel selling market in Basque ports indicates that a lack of openness in the market, the fragmentation of the sector and the high level of concentration in demand seem to be conditioning the ex-vessel prices of the fish caught by this fleet. Indeed, the high concentration of purchasers suggests that there could well be non-competitive behaviour (Prellezo *et al*., 2010; Mugerza *et al.*, 2011; Murillas *et al*., 2012).

However, the behaviour of fishermen cannot be explained exclusively on the basis of solving an economic problem of income maximisation, since there are numerous key drivers that need to be incorporated into empirical models if the dynamics of the fleets and the behaviour of fishermen themselves are to be understood (Putten *et al.,* 2011). For example, Hannesson (1998) stresses that institutional factors, such as the rigidity of the system for allocating TACs, lead in themselves to a race to catch stocks.

To sum up, a system of daily limits seems unlikely in itself to be able to solve the problems of low profitability suffered by the fishing industry. This paper does not intend to attribute exclusively to the structure of the demand and the cost functions the lack of success of the adopted management measures, or the low profitability of the Basque fleet. Other potential drivers could compromise the profitability, such as the possible overcapacity of the fleet which characterises many European fleets (COM/2015/563; COM/2014/233; COM/2013/85). In this sense, the latest reform of the Common Fisheries Policy envisaged the introduction of a system of individual, transferable rights in Member States as an instrument for reducing the overcapacity of fishing fleets (for vessels whose total length exceeds 12 m, although the Common Fishery Policy which came into force in January 2014 relaxed the 12 m requirement)[21].

The target set is a reduction in the size of the fleet that will depend, among other aspects, on its ability to generate revenue. A possible reduction in the number of vessels could help to improve the economic situation of the Basque fleet, but it could also reduce the number of jobs on board vessels, meaning that it would not help to achieve sustainability from a social perspective (Murillas *et al.*, 2012).

Finally, it is worth noting that European Commission has imposed two fines on the Spanish fleet: One for having exceeded its TAC in 2010 (forcing it to a adjust catches up to 2015) and the other one for having exceeded its TAC in 2009 (forcing it to adjust catches from 2016 onwards). The lack of responsibility of fishery managers in that previous period is now seriously harming legitimate interests and for the sustainable future of the mackerel fisheries.

5. Conclusions

This paper provides an economic analysis of the equilibrium of the mackerel fishery developed by Basque fleets. This stock is exploited by international fleets; however Spain holds around the 80 % of the total TAC allocated for the South area, with the Basque fleet being the largest one fishing for mackerel from home ports in Spain. Both inshore and offshore sub-sectors contribute to the exploitation, although higher amounts of mackerel are landed by hand-lines, purse seiners and bottom trawlers.

[21] http://ec.europa.eu/fisheries/reform/proposals/index_en.htm.

The growing interest in reducing catches and influencing the behaviour of fishermen has led to the introduction of changes in the management of this fishery, in a situation that can be extrapolated to other European fisheries. 2008 was a key year in terms of the management of the national fishery from an economic point of view, given that a new regulation based on daily limits was then introduced to affect the economic component of the fishing activity. In particular, it was expected to produce economic incentives through pushing up the ex-vessels prices. Thus, 2007 is chosen to analyse the economic structure of the fishing activity, which provides important insights to understand the degree of successful of the aforementioned regulation.

Given the empirical fishermen´s behaviour, which is characterised by following a volume-maximising strategy rather than attending to market consideration, this study considers the inverse-demand function assuming the supply is completely inelastic and does not react to price. Differences in price are most due to the fish size, the technology employed and the landed port, all of them factored by means of dummy variables into the function. The estimated inverse demand function shows a high level of elasticity, so it is only possible to achieve slight increases in price at the expense of substantial reductions in supply, implemented through significant decreases in catches. As shown in this paper, if catches are limited by a daily limit system, the average income obtained by fishermen would drop substantially. Combined with the fact that the average costs of the fleet decrease with the quantity of catches, this would mean major losses for the sector.

The cost-structure of vessels is built based on three main headings: Personnel, fuel and other maintenance and repair costs. The average and marginal cost functions are decreasing for the range of landed quantities, that is, fishing activity is located to the left of the minimum average cost. This justifies the fishermen´s behaviour of maximising revenues through catches because this behaviour also implies maximising profits. Finally, it should be noted that depending on the level of exploitation, this fishery could reach an economic equilibrium but not always at sustainable levels.

The simulations carried out in this study show that daily limits need to be accompanied by changes in the demand function, because selling prices will not cover average costs if everything remains the same. Although it remains to be seen what will happen in the coming years, for the moment the economic sustainability of the fleet cannot be seen as guaranteed.

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