Fishing Location decisions in the Chilean-Transzonal Jack Mackerel Fishery [*]

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Cra 13 # 28-01
Bogotá, Colombia

December 30, 2008

Abstract

This study examines factors conditioning the fishing location decisions of the Chilean fleet operating in the South-east Pacific straddling jack mackerel fishery, considering voyage data for the 1987-2004 period. As from the early 1990s, this fleet began to move beyond the 200 nm zone, responding to changes in the spatial distribution of the species. It is thought that this change dynamics may have been intensified by the strong 1997-98 *El Niño* event. The return of distant-water-fishing-nation's fleets to this fishery, as from the year 2000, has increased interest in understanding effects related with this spatial change dynamics. This paper is an econometric analysis of the effect of environmental, regulatory, technological and economic factors on the fishing location decisions of the Chilean fleet working in this fishery. The possible influence of *El Niño* events on the spatial operations of this fleet is tested.

JEL classification: Q22; C23; C25

Key Words: Spatial econometrics; Fishing location models; Transzonal open-sea jack mackerel fishery; El Niño phenomenon; Individual fishing quotas.

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[*] We thank Patricio Barría, Leonardo Caballero and Rodolfo Serra (of the Chilean Fishing Institute, IFOP) and René Cerda (UCV), for their collaboration in analyzing fishing and biological aspects of the fishery under study. We also express our gratitude to Marcela Perticará and Claudio Agostini (Department of Economics, UAH) for their suggestions on methodological aspects. We gratefully acknowledge data availability provided by IFOP.

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1. Introduction

The increasing exploitation of highly migratory fish resources, with population nuclei that migrate following in/out patterns in the EEZ of coastal countries, has been creating incentives to develop joint management institutions among multiple countries with interest in resources of this kind (Munro 2000; Peña-Torres et al. 1999). Some well-known examples of fisheries currently under collective management by a group of countries are the tuna fishery in the Central and Western Pacific, the Norwegian spring-spawning herring (*clupea harengus*) fishery in the North Atlantic, fished by Norwegian, Icelandic, Russian, European Union and Faroe Islands fleets, and the deep sea cod (toothfish or *dissostichus eleginoides*) fishery operated by fleets of various countries in areas under the jurisdiction of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR).

In the case of another highly migratory species, the straddling jack mackerel (*Trachurus symmetricus murphyi*) fishery in the eastern South Pacific Ocean, a round of meetings began a couple of years ago, in the framework of the South Pacific Regional Fisheries Management Organization, between countries interested in developing a future joint management system for this fishery. Among the countries currently taking part are Chile, Peru, Russia, China, the European Union, New Zealand, Australia, Canada, the USA and a set of countries with flags of convenience for fishing in international waters. To achieve progress in this direction, naturally each country must analyze the implications of possible changes in the share of different fishing zones on the annual catch it obtains in this fishery. In the case of the Chilean fleet, one fundamental aspect concerns the importance of catches obtained within and outside Chile's EEZ.

This paper econometrically models fishing location decisions of the Chilean fleet taking part in transzonal jack mackerel fishing. The industrial fishing of this species is nowadays the fishery with the greatest volume of landings in Chile. The analysis concentrates on effects related with changes in the spatial distribution of this fish stock in international waters neighboring the Chilean EEZ. There are growing signs that a displacement in the spatial distribution of large shoals of jack mackerel has been taking place towards international waters, especially since the last years of the 20th century. These signs are deduced from changes in the fishing zones reported by the Chilean fleet. It has been speculated that this shift may have intensified as a result of the strong *El Niño* phenomenon occurring during several months of 1997-1998[1] (Arcos et al. 2001; Elizarov et al. 1993).

Since the end of the 1990s, there have also been changes in the type of ships operating in the industrial fishing of jack mackerel in Chile. These changes, moreover, have taken place in parallel with important regulatory reforms implemented in the Chilean jack mackerel fishery (within its EEZ). The econometric model on fishing location decisions of this fleet will have controls for these regulatory changes and also for other effects that could be specific to the type of ship. In this context, it will be tested whether the occurrence of the *El Niño* phenomenon might constitute a conditioning factor of the spatial operation of the Chilean fleet which catches jack mackerel inside and outside the Chilean EEZ.

One important advantage favoring this econometric analysis is the availability of a database (regularly processed by IFOP – Chilean Fishing Institute) containing geo-referenced information (at fishing trip level) on the operations of the Chilean industrial fleet catching jack mackerel over almost 2 decades (1987-2004). This time period, and the consequent data variability in relevant variables, aids the testing of possible correlations between the spatial operating decisions of the Chilean fleet and a set of potential conditioning factors, among which are regulatory and technological changes, seasonal effects, extractive species-specialization patterns according to type of ship, and environmental effects. As far as we know, no analysis of this type has been made to date for the Chilean transzonal jack mackerel fishery, nor for other fisheries in which this species or any other with similar biological/migratory characteristics is caught.

It should be noted that previous econometric analyses on fishing location problems have mostly used *cross-section* data (Holland et al. 2004; Wilen 2004). Only a few studies have used sample data with a time dimension, although most of these have made analyses with daily or weekly data, without covering more than one year of fishing operations[2] (e.g. Strand 2004; Curtis & McConell 2004; Mistiaen & Strand 2000). This has limited the possibility of analyzing effects with longer frequencies of occurrence (such as, for example, the effects associated with the El Niño phenomenon).

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[1] According to some physical indices, the 1997-98 El Niño event was the strongest on record (McPhaden 1998).

[2] One exception is Smith (2002) who analyzes a random sample of 30 divers working in the sea urchin fishery in California during the 1988-1997 period.

This paper is organized as follows. The next section describes relevant aspects of the fishery under study. Section 3 discusses assumptions of the estimation methodology while section 4 discusses the variables to be considered in the estimation model. Section 5 analyses the estimation results. Finally, section 6 presents conclusions.

2. The Chilean jack mackerel fishery

The Chilean jack mackerel fishery forms part of a broad oceanic distribution of this species in the south-east Pacific (see Figure 1). As the result of a colonization process that began in the early 1970s, jack mackerel is now distributed in the south-east Pacific even beyond 1000 nautical miles from the central coast of Chile (along latitude 40°S, part of this stock even reaches the waters of New Zealand and Tasmania).[3] Although at first Chilean jack mackerel fishing mainly occurred in northern Chile, since the mid-1980s the Southern fishery has been consolidated as its main fishing grounds, representing in 2004 82% of national jack mackerel landings.

The industrial jack mackerel fishery in the southern zone of Chile, with fishing operations between 33ºS and 41ºS (zone B in Figure 1), is nowadays the most important in Chile in catch volume terms: in 2007, the annual quota allocated to this industrial fleet was 1.25 million tons (78% of the national annual quota for this species). Jack mackerel fishing is mainly concentrated in industrial seiners. This fleet also catches other pelagic species, of which the main ones are sardine (*clupea bentincki*) and anchovy (*engraulis ringens).* Nevertheless, since the mid-1980s, jack mackerel has become the predominant target species in this fleet. In the 1985-2002 period, jack mackerel represented more than 80% of the total industrial catch obtained in this fishery.

At the start of the 1980s, the Southern fishery experienced buoyant investment in fleet and processing plants, which at first triggered a steady growth in catch levels, though it finally led to over-exploitation of the fish stock. The estimated jack mackerel biomass peaks in Chile and in its neighboring waters occurred in the 1986-1990 period. Since then, there has been a downward trend in the abundance of Chilean jack mackerel (Peña-Torres 2002a, Serra 1998; see Figure 2).

Related with these changes in stock abundance and in its spatial distribution, the latter inferred from the yields obtained in different fishing zones, the Chilean fleet since the early 1990s began to direct part of its fishing effort beyond the Chilean EEZ. This required investment in ships with greater

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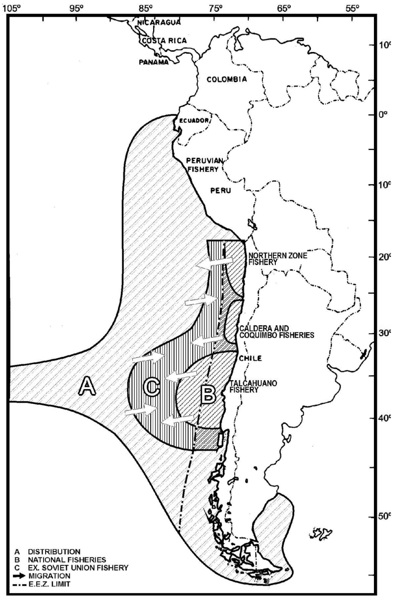
[3] Some scientists have proposed that all this jack mackerel distribution may be part of a single stock (Elisarov et al. 1993). Others have suggested the existence of three different stocks, independent of each other from a reproductive point of view: a Chilean stock, one Peruvian and another Oceanic (Serra 1991).

displacement capacity and with larger holds (>800m^3). By 1995, the number of ships in this category represented 33% of the total industrial fleet in this fishery. By 2002 that proportion was 81%.

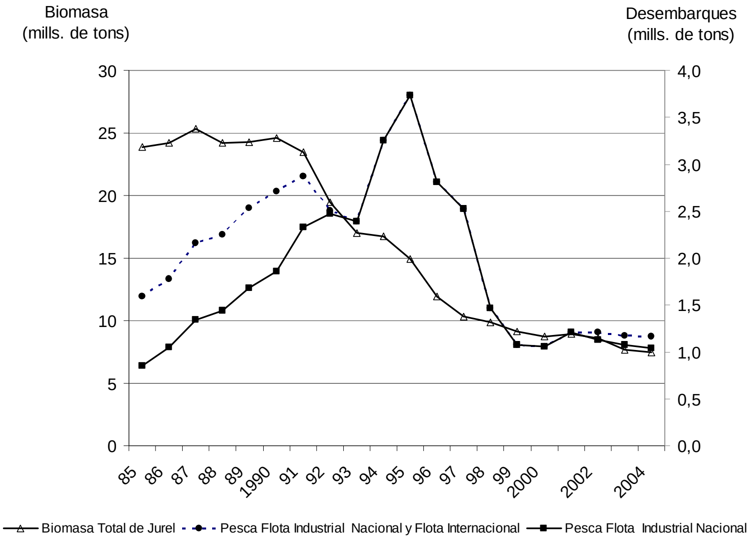
Figure 1



Source: IFOP

Figure 2

Total Chilean jack mackerel biomass * and Industrial Harvest



Source: (Peña-Torres and Cerda, 2006)
*/: Official IFOP estimation for jack mackerel stock in Chilean EEZ and international seas in front of Chilean coasts (until 120° aprox.)

The growing operation of the Chilean fleet in waters outside Chile's EEZ was driven by the increase in the abundance of jack mackerel in those zones, together with lower quantities of jack mackerel within the Chilean EEZ. This operational adjustment was aided by the disappearance of the Soviet fleet which had fished jack mackerel since 1992 in international waters near Chile's EEZ.

Indeed, during the whole decade of the 1980s a Soviet-supported distant mid-water trawl fleet operated offshore of the 200 n.m. off Peru and Chile. Its jack mackerel fishing operations ended in 1992, after the collapse of the ex-USSR. At the end of the 1980s, this fleet caught 850 thousand tons/year of jack mackerel in areas neighboring the Chilean EEZ (Crone-Bilger, 1990). After a decade without significant incursions by foreign fleets in the zone, as from 2002 the operation of factory ships from Japan, Korea and China was reactivated, the most numerous of which were ships under the Chinese flag. Official estimates in Chile (IFOP) for the year 2004 report 130 thousand tons of jack mackerel fishing by these foreign fleets in waters adjacent to the Chilean EEZ.[4]

There have been suggestions that the downward trend in jack mackerel abundance within Chile's EEZ may have been aggravated by the occurrence of the strong 'El Niño' phenomenon which began in May 1997 and continued up to mid-1998 (Arcos et al. 2001; Peña-Torres et al., 2000). This could also be associated with changes in spatial distribution and the population densities of jack mackerel off the coast of Chile. The following Table 1 reports the annually estimated spawning stock of jack mackerel in Chile's EEZ, based on hydroacoustic methods, which as from 2003 also include assessment areas between 200 and 400 miles from the Chilean coast. The results of these surveys suggest a growing proportion of spawning stock located in waters outside the Chilean EEZ.

Table 1: Hydroacoustic Estimates: Jack Mackerel Spawning Biomass*/
(1,000 tons)

Year	between 5-200mn	bt. 200-400mn	Total
1997	3,530	-	
1998	3,200	-	
1999	4,100	-	
2000	5,600	-	
2001	5,950	-	5,950
2002	1,990	-	1,990
2003	881	1,759	2,640
2004	540	3,380	3,920
2005	510	3,600	4,110

Source: IFOP (P. Point presentation), '*Jack Mackerel Fisheries: Southern pelagic fishery zone, situation 2006-2000*', August 2007, in Spanish.
*/: As from 2003, the hydroacoustic survey has included an additional area outside the EEZ, in particular from 200 to 400 nm, between 40º and 42º LS. The area traditionally surveyed has included between 0-200 nm, from 33º to 40ºLS.

In relation to this change in the spatial distribution of Chilean jack mackerel, it has been suggested that there may be two population nuclei of jack mackerel off the coast of Chile, the first off the Talcahuano fishery and the second near the island of Chiloé (41º-42ºS), the latter located in water near 200 nm.[5] Following this hypothesis, what may have happened post the 1997-98 El Niño is a modification in jack mackerel density in each of these population nuclei, increasing the density associated with the second nucleus.

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[4] Estimates by Chilean business people mention an amount of 700 thousand tons of jack mackerel fishing expected for the year 2008 by foreign fleets currently operating in areas adjacent to the Chilean EEZ (El Mercurio, Feb/11/2008).

[5] We thank the marine biologist, Patricio Barría (staff of IFOP) for mentioning this hypothesis to us.

When a population grows as did that of jack mackerel during the 1970s and 1980s, its range of spatial distribution typically increases. In fact, during its colonization phase in the south-east Pacific, from the early 1970s, jack mackerel even reached Tasmania. Equivalently, when the abundance of a species begins to diminish, as seems to have been happening with Chilean jack mackerel since the beginning of the 90s, it would be reasonable to expect that its geographical distribution would tend to contract towards those habitats best adapted to the species. Studies on the operation of the Russian fleet during the 1980s, in international waters adjacent to the EEZ of Chile, indicate that already before 1989 there were important fishing operations outside 200 nm, off and to the south of the island of Chiloé (Parrish 1989). Thus, the recent geographical shift of fishing operations of the Chilean industrial fleet which nowadays catches jack mackerel could well reflect changes in population densities of different nuclei of jack mackerel off the coasts of Chile.

In this context, this paper analyzes empirically the influence of different determinants on the fishing location decisions of the industrial fleet operating in the Southern fishery of jack mackerel in Chile. Information is used for this at fishing-trip level, covering the total number of fishing trips reported for this fleet during the 1987-2004 period.

3. Data and econometric modelling assumptions

The basic source of information is from the logbooks of the whole Chilean industrial fleet operating in the Southern Chilean pelagic fishery, which are in the records of the Chilean Fishing Institute (IFOP). This database provides information per vessel ($i=1,\ldots,N$, with $N=278$) and per fishing trip. The data used in the regressions cover a total of 18 years (1987-2004), and include observations for more than 210 thousand trips, with an average of 475 trips per vessel in the estimation sample. In the estimation exercises all explanatory variables are defined at monthly level, so the time series dimension of the estimation sample is 216 months.

The database records the vessel code, hold capacity of each ship, date and time of departure and arrival of each fishing trip, latitude and longitude at which it is reported the main fishing cast per trip, as well as the volume caught in each trip, differentiating five species, including jack mackerel.

A first definition concerning the econometric model to be estimated refers to the ‘discrete versus continuous’ nature of the spatial choices under analysis. Most of the empirical studies made up to now on spatial decisions of fishing fleets have modelled this kind of problem considering a finite number of fishing zones. Econometric modelling has thus typically considered endogenous variables of a discrete type (e.g., Bockstael & Opaluch 1983; Eales & Wilen 1986; Holland & Sutinen 2000; Smith 2000; Mistiaen & Strand 2000). However, the validity of this modelling strategy is conditioned by the type of fish stock involved and finally by how the fishing location decision is really made.

In the case of the fleet under analysis, modelling discrete choices is not necessarily the most suitable form of analyzing the fishing location decision, especially because of the not fully predictable migrations of jack mackerel. Given the broad spatial distribution which jack mackerel reaches at particular times of the year, and even supposing that the ships start their fishing trips with a particular destination, during the trip it is perfectly possible that they come across significant shoals and that fishing takes place before expected, or the contrary. In the case of pelagic fish, such as jack mackerel, there are no completely stable and predefined fishing areas. The highly migratory patterns of jack mackerel increase the uncertainty involved in these decisions.

Therefore, in this paper it is assumed that the process of searching for shoals occurs in a continuous way, since the ships in the Chilean fleet fishing outside the EEZ necessarily have to previously cross inside the 200 nm, and so it is supposed that they decide to fish outside the EEZ only if they do not manage to fish inside it.

A second aspect to be defined is whether or not the fishing location decision of each vessel will be considered an event independent of the spatial decisions of the rest of the fleet. In this case, we have no information that enables us to justify a specific mechanism of transmitting information about fishing zones to be prioritized in the shoal-searching efforts (e.g., Lynham 2006; Curtis & McConell 2004; Smith 2000). Neither do we have information about the ownership by company of the different ships taking part in those search efforts. For this reason, and to simplify, we do not explicitly model any specific information transmission mechanism between vessels.

Nonetheless, and related to the calculation of a control variable that will approximate the formation of expectations on fishing yields obtainable in different fishing zones when deciding on each fishing trip, this variable will be calculated as a moving average of the reported yields, in the four-week period immediately prior to the start of each trip, for the total of vessels which have made fishing effort in a particular zone. This presumes the existence of some ex-post information transmission process between ships about the fish yields obtained in different fishing areas.[6]

A third definition concerns the possible modelling of correlation between the fishing yields obtainable in neighboring areas. For example, statistical techniques have been developed to predict the spatial variation in catch yields, within particular adjacent areas.[7] However, this type of analysis goes beyond the first-approach aim of this study. Our estimation methodology will thus assume that catch yields are independent between one zone and another.

This study develops an econometric model for three endogenous variables, all directly related with the fishing location decision. It models: (i) trip duration, (ii) the longitudinal location at which the (main) catch of each trip is reported and (iii) the latitudinal location of the fishing reported in each trip. The 'trip duration' variable is a proxy for the fishing effort performed, while variables (ii) and (iii) control for the spatial dimension of this effort (coordinates of longitude and latitude), according to the reported fishing zones. To explain each of these three variables, the same set of explanatory variables will be used. These variables control for seasonal and environmental effects, regulatory changes and technological as well as economic aspects of the fleet being studied.

The estimation method applies the algorithm for fixed-effects panel data, which introduces dummy variables as additional controls, which are vessel-specific and time invariant. This enables non-observable vessel-specific factors to be controlled for (e.g., technological characteristics not statistically recorded, or the fishing experience of the vessel's crew), which are assumed to be time invariant. In addition, in order to test dissimilar effects depending on vessel size, given the various patterns of fishing specialization by ship size which we describe below, the estimation model will also include interactive terms between dummy variables defined by 'size (of hold) of the ship' and the controls for seasonal, regulatory, price and technological change effects. The econometric estimation of the three endogenous variables is performed independently.

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[6] It should be noted that the different companies (currently, 11) owning industrial vessels operating in Chilean transzonal jack mackerel fishing jointly run a private fisheries research institute (INPESCA), which periodically receives geo-referenced information on the jack mackerel catches obtained by each industrial vessel taking part in the Southern Chilean jack mackerel fishery.

[7] For example, the calculation of semivariograms is used to predict spatial variations in the productivity of fishing in zones in which information is not available, based on information on catches observed in neighboring zones (Fleming 2000; Cressie 1993).

Under the assumption of strict exogeneity of the regressors, i.e. $E[u_{it}/X_{it},f_i]=0 \ \forall t$, where $E[./.]$ denotes conditional expected value, u_{it} the estimation residuals, X_{it} the vector of regressors and f_i the vessel(i)-specific fixed effects vector, the fixed-effects panel estimation produces consistent estimators of the coefficients in the model to be estimated, allowing for the existence of arbitrary correlation between the regressors X_{it} and the fixed effects f_i (Wooldridge, 2002). Also, even though the estimation algorithm for fixed-effect panel data generates – by construction – serial correlation in the estimation residuals u_{it}, such that $Corr(u_{it}u_{is})= -1/(T-1)$, with $t\neq s$ and T equal to the time series dimension of the sample data, in our case (T=216) the quantitative relevance of the serial correlation effect is clearly reduced.

4. Variables in the estimation model

Dependent variables

The econometric model concentrates on analyzing fishing trips in which the fish mainly caught, or target species, was jack mackerel. There is, however, a significant quantity of trips (50,899) in which no catches were reported. These observations correspond to unsuccessful fishing trips. It is not possible to know *a priori* what the fishing purpose (or 'target species') of each of these was. If these trips are eliminated from the estimation sample, the estimated parameters could be biased. To deal with this risk, a criterion is defined to assign a 'target species' to each of these trips (see Appendix 1).

The three endogenous variables are defined as follows:

(E1) Fishing trip duration

Fishing effort could be interpreted as a measure of the set of variable inputs (e.g. fuel use, crew's labor efforts) that vessels devote to fishing. Supposing fixed proportions in the use of different variable inputs, the trip duration – measured by the total hours of sea operations – approximates the intensity of use of the variable inputs required for fishing.

In this study, the total fishing effort per vessel is modelled, both when looking for shoals as well as when performing fishing tasks, including unsuccessful fishing trips. The log-books collected by IFOP identify the date and time of departure and arrival of each trip, which enables the total duration (in hours) of each trip to be calculated.

Given that there is no data censoring in the observation of the duration of the fleet's total fishing trips, the estimation algorithm for fixed-effects panel data provides results equivalent to those obtainable by estimating a (trip) duration model.

(E2) Longitudinal distance from the coast at which the main cast (per trip) is made

This measure is calculated on the basis of the reported meridian coordinate of the main fishing cast per trip. An Excel program was drawn up for calculating the distance (in nautical miles) between the coordinate where the main fishing cast is reported and the corresponding coordinate (projected following the same parallel) on the coast. This measure of longitudinal distance corresponds to the second dependent variable in our econometric model.

(E3) Parallel at which the main cast is made per trip

This variable measures the North/South location of the main cast reported per fishing trip. The parallel associated with each cast reports the latitude of each reported fishing cast.[8]

Independent variables

The explanatory variables used to control for relevant determinants of the endogenous variables in the estimation model are defined below.

(i) Seasonal Factors

Experts in this fishery suggest that, during the first six months of the year, jack mackerel tend to gather in shoals with greatest density within the Chilean EEZ, migrating during the second half-year towards waters outside the 200 nm zone.[9] The months when jack mackerel shoals are located closer to the coast tend to coincide with the high fishing season for this fish stock.

To control for this seasonal effect, a dummy variable is used that divides the year in exclusive halves. This variable is denoted as *High_S* and has a value of 1 for the months between January and June, and 0 otherwise.

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[8] The latitudinal coordinates (parallels) used correspond to those calculated after transforming the original data (in sexagesimal system) into coordinates expressed in the decimal system.

[9] On this issue, we thank Patricio Barría, Rodolfo Serra, Leonardo Caballero (all IFOP staff) and René Cerda (UCV).

(ii) Technological Aspects

Hold capacity and fishing specialization patterns

In this fleet, the best proxy for fishing capacity is given by the hold volume of each vessel. Additionally, ships in different categories by hold capacity tend to specialize in different target species. This is related with the spatial distribution of each species: sardine and anchovy are basically coastal species, while jack mackerel presents a more oceanic distribution. Hold capacity is positively correlated with the displacement capacity and geographical coverage which each ship can achieve.

Vessels in the larger size categories tend to devote a higher proportion of their fishing efforts to areas more distant from the coast and, related with this, tend to specialize in jack mackerel fishing. Ships in the smaller size categories concentrate their fishing effort in areas closer to the coast, and so their preferred target species are sardine and anchovy (Peña-Torres & Cerda 2006).

To control for these patterns of fishing specialization, three 'hold size' categories are defined according to the following dummy variables:

- *B1* groups the smaller industrial vessels: it takes value 1 when the hold capacity is less than or equal to 370 tons and value 0 otherwise. In the estimation exercises, this category corresponds to the excluded group.
- *B2* groups the medium-size vessels: it takes value 1 when the hold capacity is greater than 370 tons and less than or equal to 790 tons, and value 0 otherwise.
- *B3* groups the larger vessels: it takes value 1 when the hold capacity is greater than 790 tons and value 0 otherwise.

Prior studies on this fleet have corroborated that this categorization robustly captures the statistically significant differences in fishing productivity between vessels, according to their hold capacity (Gómez-Lobo et al. 2005; Peña-Torres, et al. 2004).

Cold Storage Capacity on Board

In this fleet, above all in the larger size vessels, the incorporation of cold storage dates back more than a decade: in 1992 there were already ships in this fishery which had cold storage systems on board. Consistent with this, from the early 1990s this fleet began to gradually shift part of its fishing effort outside the 200 nm zone.

In the industry that supports this fishery, the freshness of the landings is an important condition for achieving higher value products (e.g., prime fishmeal and surimi). Having cold storage on board facilitates this kind of production, enabling trips to more distant zones to find more productive fishing grounds.

The information available does not allow us to control for the existence of cold storage capacity at ship level. To control globally for changes occurring in this area, a dummy variable is incorporated that differentiates the period as from which on-board cold stores began to be increasingly incorporated. Thus the variable D_1990 is defined, which takes a value of 1 as from January 1990 and value 0 otherwise. [10]

(iii) Environmental Aspects

In order to control for the possibility that the endogenous variables have been affected by environmental factors, a variable is defined associated with the occurrence of the El Niño phenomenon, a disturbance that is related, among other effects, with changes in the sea surface temperature. The Oceanic El Niño Index (ONI), calculated by the National Oceanic and Atmospheric Administration of the USA (NOAA), was used to control for this phenomenon. [11]

The ONI index is constructed as the three-month moving average of anomalies in the sea surface temperature (SST), compared to its average level during the reference period 1971-2000, measured in the zone known as Niño 3.4 region (120ºW-170ºW, 5ºN-5ºS).[12] According to the criteria used by the NOAA, the occurrence of *El Niño* events is defined when for 5 consecutive months the anomaly (or deviations) of SST heating is equal to or greater than +0.5°C.

The occurrence of this phenomenon is controlled for in the estimation model through a dichotomous monthly variable, denoted *Niño*: it takes a value of 1 when an episode of a rise in SST (measured by the ONI) greater than or equal to +0.5º occurs in month t and during at least the previous four

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[10] We tested the statistical relevance of using other start months for this structural break. January 1990 was the month that gave greatest consistency and robustness in the estimation results. We thank L. Caballero (IFOP) for his help in defining which period to consider in relation to the start of this process of technological change.

[11] See http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

[12] The use of this ONI index was suggested by IFOP marine biologists. The Niño region 3.4 contains a cold water zone which extends along the Equator, from the South American coast to the central Pacific Ocean. Variations in the SST in this region play an important role in temperature and precipitations models worldwide. For more detail on the justification of using the ONI index in relation to the Chilean jack mackerel fishery, see Yepes (2004).

months, and has a value of 0 otherwise.[13] To test the robustness of the effects to be estimated for this environmental change measure, this variable will be initially measured in months contemporaneous to the endogenous variables' time occurrence, but its effects will also be tested by considering up to 6-month and 12-month delayed effects, thus allowing for its effects to be persistent.

From the start of the 1990s, this fleet's operations began to shift beyond the 200 nm zone, responding to changes in the spatial distribution of the jack mackerel. It has been suggested that these changes may have intensified with the arrival of the strong 1997-98 *El Niño* event. To test the validity of this hypothesis, a dichotomic variable is defined that controls for any 'structural break' in the fishing location decisions in the Chilean jack mackerel fishery, related with the strong El Niño phenomenon occurring between May 1997 and April 1998. We denote this variable as *D_May97*: it takes a value of 1 as from May 1997 onwards and value 0 in the remaining months in the sample.[14]

(iv) Regulatory regimes and maximum catch limits

Dichotomic variables are used to differentiate three regulatory periods, each one involving different fishing regulations (more details at Peña-Torres 2002; Gomez-Lobo et al. 2007).

The first period corresponds to an 'olympic race' (OR) regime. Along this period, given the absence of fishing quotas (global and individual) and despite entry to this fishery being restricted, each vessel's fishing incentives consisted in maximizing catch volume in the shortest time possible (Peña-Torres and Cerda 2006). The corresponding dummy is denoted by *OR* and takes a value of 1 for the months included between January 1985 and November 1997 and also in January 2001, and 0 in any other case. This period corresponds to the excluded category in the estimations.

The second regulatory period corresponds to the so-called '*Research Fishing'* regime*,* which begins in December 1997 and ends in December 2000. This regime combines periods of transitory fishing bans with simultaneous fishing authorizations for a restricted number of industrial vessels. Thus,

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[13] This dichotomic-type measure aims to control grossly, but robustly, for rather more qualitative type changes occurring in relevant oceanographic-biological type variables.

[14] Different months of 1997 were tested as the starting period of this possible structural break: May was the month that obtained the greatest t-statistic value.

chosen vessels were able to participate in a series of 'research fishing' expeditions.[15] The sector regulator defined ex-ante the permitted operation dates and the coordinates between which each vessel should carry out its tasks. Participant boats had to sweep a pre-determined stretch of sea and locate existing schools of fish. This information was used by the authorities to gauge with more precision the level of fish biomass and its distribution. Once each expedition was over, participant boats had the right to capture a pre-allocated quota of jack mackerel per vessel. By implementing this regulatory system, the authorities also sought to keep processing plants in operation aimed at human consumption.[16]

These controlled fishing expeditions, besides reducing the effort exerted on the fish stock, operated in practice as a pseudo-individual quota system that served to show companies the benefits of such a system. Until then the management of fisheries in Chile was for the most part based on the use of a yearly global quota (TAC), effort restrictions (licenses) and seasonal closure of fisheries justified on biological considerations. Compared to the previous 'Olympic race' for resources, the individual quotas assigned to participant ships during the 'experimental' fishing expeditions allowed fishermen to optimize the use of their fleet.

To control for the currency of the 'fishing research' period, a dummy variable is used and it is denoted by *RF,* which takes a value of 1 between December 1997 and December 2000, and 0 in any other month.

In the third, still current regulatory period, maximum catch quotas are set per vessel owner. This scheme, started as from February 2001, distributes throughout the year (considering quarterly quotas[17]) the annual overall quota allocated to the industrial fleet, distributing fishing quotas per owner (by percentages previously defined by law and not allowing property rights over these quotas to be transferred) to the owners of vessels with current authorizations to fish in this fishery.

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[15] The Fisheries Regulatory Agency first made a pre-qualification list of potential ships to participate in each expedition. To qualifying boats had to comply with certain features (e.g., a minimum hold capacity (≥700 m3), a valid fishing license, GPS and sonar technology, and to accept an official monitor on board, among other requirements). Then vessels were randomly selected among the pre-qualified list.

[16] Peña-Torres (2002) and Gomez-Lobo et al. (2007) explain the economic policy reasons underlying the use of the RF system to regulate fishing operations in this fishery.

[17] In the case of jack mackerel, this intra-annual allocation usually consists of 40%, 40%, 15% and 5% of the overall annual quota for each correlative quarter in the year. This distribution is consistent with the jack mackerel fishing seasons.

A fundamental difference between this third regulatory period and the previous one is that from February 2001 onwards, the holders of fishing quotas have complete freedom of operation to decide when (within each year), how much (of the quota available) and with which of the vessels with current authorization, they will carry out fishing tasks (Peña-Torres 2002; Gómez-Lobo et al. 2007). The currency of this regulatory regime will be controlled by a dummy variable denoted by *IQ (Individual Quotas)* and taking a value of 1 between February 2001 and December 2004, and 0 in any other month.

(v) Jack mackerel abundance

As proxy for the abundance of this fish stock, the aggregate landings of jack mackerel are used, grouped at quarterly level, of the whole of the industrial fleet. This variable is grouped quarterly to minimize any possible endogeneity bias in the estimation model of the 'trip duration' variable. This aggregate landings variable is denoted by *Qmax*.

In the estimation model, a simultaneous control with proxies associated with the level of available biomass of jack mackerel, on the one hand, and the global fishing quotas current in different periods, on the other, is not used, in order to avoid statistical problems associated with the use of variables measured with error (biomass), possible endogeneity biases and also estimation efficiency problems in the estimates arising from multicollinear regressors (see Peña-Torres, Agostini & Vergara, 2007).

(vi) Price effects

To control for changes over time in the per unit profitability of the fishing business, the quotient (in logarithm) between the fishmeal price and the fuel price is introduced as a regressor, with both prices calculated as a monthly average and both measured in months contemporaneous to the catch records (ln_price_ratio). During the period under analysis, fishmeal production constituted the main destination of the jack mackerel landings. Thus the average fishmeal price is used as a proxy of the final unit value of the landings. On the other hand, fuel expenditure in this fleet represents nearly 80% of the total variable costs per fishing trip (Gómez-Lobo et al. 2005). Appendix 2 describes the sources of information and the method used for building the time series for this quotient.

(vii) Expectations of catch yield by fishing zone

In the estimation model there is control for the formation of expectations on catch yields per unit of effort according to fishing area, using as a regressor the four-week moving average[18] of the mean fishing productivity reported for the total of vessels which, in that four-week period, reported successful casts in a given fishing area.

To calculate this productivity variable by fishing zone, 4,410 sea areas are originally defined, considering 126 partitions latitudinally and 35 longitudinally, each area with dimensions of 5 minutes as latitudinal range and 20 nautical miles as longitudinal range. Given that fishing is not reported in all the resulting areas, the estimation exercises finally consider 1,187 areas visited by the fleet analyzed during the sample period.

The calculation of mean fishing productivity in week t and in zone j corresponds to the average of the catches (kilos of jack mackerel) reported by the total of vessels which made casts during week t in zone j, each catch tonnage reported being divided by a measurement of fishing effort made in that trip.[19] In the case of the equation that models trip duration, the measurement of effort is the linear distance (in nautical miles) calculated as run by the ship in each trip, whether or not the fishing was successful. For the other two dependent variables, the duration of the trip is used as proxy of fishing effort. These changes in the denominator of the proxy variable for the productivity expectations, by fishing zone, seek to avoid possible endogeneity biases.[20]

(viii) Other controls

Lastly, the following dichotomic controls are used to identify the port of origin in each trip:

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[18] The four-weekly periodicity (the last 4 weeks prior to the date of the reported fishing cast) permits a control for the change in productivity indices (by fishing zone) as the seasonality pattern changes. Experts in this fishery confirmed the empirical relevance of a four-weekly frequency to calculate this moving average. (We thank L. Caballero for this). Alternative estimations were also made taking into consideration two variants for the calculation of this variable, i.e. taking the last 6 and 8 weeks for this calculation. The estimation results are robust to these variants (details can be requested from the authors).

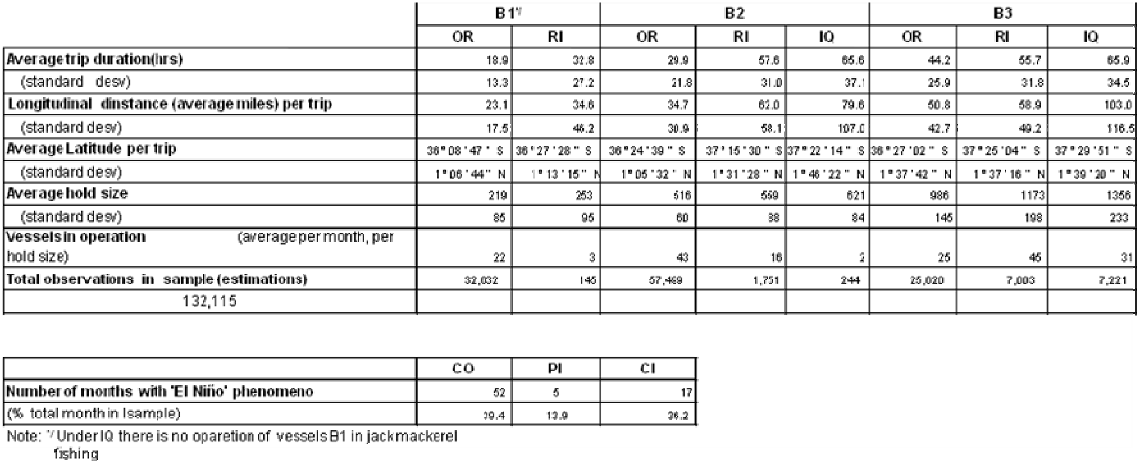
[19] If the fishing productivity calculation per zone were not explicitly considered a measure of fishing effort, undesired biases would occur. For example, more distant zones, with fishing predominantly by vessels with larger hold as well as manoeuvring capacity, would tend to present a spurious correlation with 'greater fishing productivity', since larger vessels tend to land greater tonnages of fish in each trip.

[20] For example, if this variable considered always the ‘trip duration’ in its denominator, variations in this regressor could present correlation with the estimation residuals of the model defined for the dependent variable ‘trip duration’. In this case, the coefficients estimated would be biased and inconsistent.

- *Port5*: takes value 1 if the vessel leaves from the port of San Antonio (located in the 5th administrative region of Chile) and 0 otherwise. It will be the base category (of region of origin) or excluded in the estimation exercises.
- *Port8*: takes value 1 if the vessel leaves from any port of the 8th administrative region of Chile (which includes the fishing ports of Tomé, Talcahuano, San Vicente, Coronel or Lota) and 0 otherwise.
- *Port10:* takes value 1 if the vessel leaves from the port of Corral (located in the 10th administrative region of Chile) and 0 otherwise.

The Table below provides a summary of the average values of some of the variables in the estimation model, differentiating the three categories of hold size and the three regulatory periods.

Table 2: Average values sample data, by regulatory period
(Sample period: 1987-2004)



	B1[1/]		B2			B3		
	OR	RI	OR	RI	IQ	OR	RI	IQ
Average trip duration(hrs)	18.9	32.8	29.9	57.6	65.6	44.2	55.7	65.9
(standard desv)	13.3	27.2	21.8	31.0	37.1	25.9	31.8	34.5
Longitudinal dinstance (average miles) per trip	23.1	34.6	34.7	62.0	79.6	50.8	58.9	103.0
(standard desv)	17.5	46.2	30.9	58.1	107.0	42.7	49.2	116.5
Average Latitude per trip	36°08'47' S	36°27'28" S	36°24'39" S	37°15'30" S	37°22'14" S	36°27'02" S	37°25'04" S	37°29'51" S
(standard desv)	1°06'44" N	1°13'15" N	1°05'32' N	1°31'28" N	1°46'22" N	1°37'42" N	1°37'16" N	1°39'20" N
Average hold size	219	253	516	569	621	986	1173	1356
(standard desv)	85	95	60	38	84	145	198	233
Vessels in operation (average per month, per hold size)	22	3	43	16	2	25	45	31
Total observations in sample (estimations)	32,032	145	57,469	1,751	244	25,020	7,003	7,221
132,115								

	CO	PI	CI
Number of months with 'El Niño' phenomeno	52	5	17
(% total month in Isample)	39.4	13.9	36.2

Note: [1/] Under IQ there is no oparetion of vessels B1 in jackmackerel fishing

Source: Own elaboration based on IFOP information

5. Estimation results

The next table shows the estimation results for the three endogenous variables under study[21]. All the variables introduced into the three equations are expressed in logaritms except those that are dummy variables. All the models satisfy the log likelihood test for global significance (likelihood

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[21] Other specification were estimed as well, considering variants in environmental variables definition, time lags in the price ratio value that is used as proxy for changes in fishing rentability business , and in the number of weeks considered to calculate the expected productivity per fishing zone. The reported model is that one that presented highest robustness and consistency in signs and statistical significance in the estimed coefficients.

ratio in Table 3). The estimations are performed using the Huber-White peocedure, which allows obtaining robust standard errors in the presence of heterocedasticity and/or not normality in them.

- Seasonal and environmental factors, and dtructural change

According to the 'high fishing season' definition, months when jack mackerel shoals are located specially into the Chilean EEZ, the estimation results corroborate that from Januеary to June, the fleet reduces the average duration of the fishing trips. This effeft is statistically significative for the 3 hold size vessels and the reduction of trip duration increases as greater is the size of the vessel in operation (the last respect the duration fishing trips in the second semester of the year, i.e., the low fishing season).

In terms of North/South reported coordinate in each trip, in high fishing season the vessels in the default category (vessels that operate more frecuentrly near the coast) in average report the main cast further to the south than those made in low fishing season. The effects for B2 an B3 categories are statistically significative as well and have the same impact sign; nevertheless, in this two cases the southern movement of the main fishing cast during first semester, is smaller.

In relation to the reported longitude for the main fishing cast in each trip, in high fishing season those reports are closer to the coast in average (versus low season). The last is true for the three vessels categories and this effect is maxim for vessels B3. Remember that the last category includes vessels with major capacity to move toward the high seas and those vessels are more specialized in jack mackerel fishing.

Regarding to El Niño phenomenon and considering *contemporary effects* on the variables under study (see Table 4), there is a group of statistically significative effects. First, during the low fishing season, the El Niño phenomenon reduces the trip fishing duration and moves them further to the south and near to the coast. In high fishing season the statistical significancy of those effects holds, but now El Niño phenomenon (i) increases the trip duration, (ii) reduces the South tendency of the latitudinal main cast coordinate and (iii) it continues producing that, in average, main cast are located near the coast, nevertheless El Niño impact is now smaller.

In order to analize the signs robustness and statistical significance of the effects associated to El Niño phenomenon, there were performed others estimations where *Niño* variable was introduced supposing that its effects last more than the moth in wich this environmental phenomenon takes place. There were considered two alternatives: In one case, the Niño variable was equal to 1 if El Niño has occurred in at least one of the last six months previous to each trip; in the other case, El Niño is equal to 1 if the last mentioned ocurres in at least one of the last twelve month previos to each trip.

Table 3: Estimation Results

Data Panel Regresion with fixed effects and robust standard errorrs[a]	Observations per vessel		min: 1
Number of observations: 132115			average 475.5
Number of vessels 278			max: 1590
RESULTS:	**Dependent Variables**		
Independent Variables	Trip Duration (hours)	Longitudinal distance at which the main cast is made	Parallel at which the main cast is made
High_S	-0.04418 ***	-0.22309 ***	0.00389 ***
High_S*B2	-0.04031 ***	-0.01478	-0.00173 ***
High_S*B3	-0.11951 ***	-0.04882 ***	-0.00213 ***
Niño	-0.03704 ***	-0.10701 ***	0.00813 ***
Niño*High_S	0.04594 ***	0.07805 ***	-0.00721 ***
D_May97	0.10022 ***	0.10152 ***	0.02174 ***
Niño*D_May97	0.08068 ***	0.08466 ***	-0.02417 ***
Niño*D_May97*High_S	-0.10335 ***	-0.24740 ***	0.02321 ***
RF	-3.17665 **	-2.58122	-0.00689
RF*B2	3.54595 **	2.42156	-0.05708
RF*B3	3.66916 ***	3.47728 *	-0.15096 ***
IQ (only B2)	3.74073 ***	-1.21272	0.10172 *
IQ*B3	-1.13973 *	0.73032	-0.15308 ***
D_1990	0.09539 ***	-0.04363 ***	-0.00439 ***
D_1990*B2	0.22129 ***	0.19278 ***	0.00561 ***
D_1990*B3	0.35525 ***	0.39782 ***	0.01363 ***
ln_Qmax	0.11849 ***	0.20269 ***	-0.00133 ***
ln_Qmax*B2	0.00176	0.05896 ***	-0.00235 ***
ln_Qmax*B3	-0.03926 ***	0.07529 ***	-0.00633 ***
ln_Qmax*RF	0.30579 ***	0.23489	0.00233
ln_Qmax*RF*B2	-0.29192 **	-0.19256	0.0062
ln_Qmax*RF*B3	-0.31604 ***	-0.28584 *	0.01396 ***
ln_Qmax_IQ	-0.31340 ***	0.02208	-0.00817 *
ln_Qmax*IQ*B3	0.08652	-0.05228	0.01368 ***
ln_price_ratio	0.01832	0.08739 ***	0.00056 *
ln_price_ratio*B2	0.32972 ***	0.13538 ***	0.00124 **
ln_price_ratio*B3	0.13112 ***	-0.29275 ***	0.01259 ***
ln_prod_zone	-0.01749 ***	0.00852 ***	0.0003 **
ln_prod_zone*D_1990	0.01739 ***	0.01149 ***	-0.00034 ***
ln_prod_zone*D_May97	-0.00775 ***	-0.05340 ***	0.00028 ***
Port8	0.05075 ***	-0.06055 ***	0.06734 ***
Port10	-0.49900 **	-0.52702 **	0.10068 ***
Port8*RF	-0.22217 ***	-0.02571	-0.03768 ***
Port8*IQ	0.36071 *	1.23773 ***	-0.01136
Port10*RF	-0.11034	-0.02054	-0.03126 ***
Port10*IQ	0.74135 **	1.45630 ***	-0.02383
Constant	12.77751 ***	0.27629 ***	12.77751 ***
LR TEST Chi (36)	16129.56	13249.49	9302.78

LR TEST Chi (36)	16129.56	13249.49	9302.78

a/: Robust standard errors in posible presence of heterocedasticity and/or not normality in them, according Huber-White procedure .

*: significative at 90% of confidence; **: significative at 95%; ***: significative at 99%

With El Niño definition during the last 6 months, almost all the estimated coeficients hold their impact sign and significance.[22] The results are less stable when there is considered 12 lag months in environmental variable. However, in the last case the changes are all focused in some parameters related to El Niño phenomenon, while the results for the other controls keep equal in cualitative sense (statistical significance and signs) in the 3 estimated equations.

In therms of a possible structural change since May of 1997, the results present statistically significative effects: in this sub-period the average trip duration increases, while the main fishing casts are reported further to the high seas and further to the South.

In realtion to the El Niño phenomenon effects, there are statistically significative changes since May of 1997 as well (Table 4): Since then, El Niño in low fishing season *increases* the average trip duration, while it *reduces* it in high season. In terms of reported longitudes, in low season El Niño makes the casts near to the coast, although this effect is smaller than previous May of 1997; in high season the 'closer to coast' effect holds, but since May of 1997 this effect increases. In terms of the North/South coordinate, since May of 1997 El Niño appears associated with casts further to the North, result that is true in high and low seasons. The next table resumes the net values of the coefficients, according fishing season and period pre or post structural change.

Table 4: Contemporary El Niño Phenomenon Effects

Dependent Variable	Fishing season		
	Low	High	
Trip duration			net value
Niño	-0.03704	0.04594	0.00890
Niño*D_May97	0.08068	-0.10335	
net value (post May 97)	0.04364	-0.05741	-0.01377
Longitudinal distance (n. miles), main cast			net value
Niño	-0.10701	0.07805	-0.02896
Niño*D_May97	0.08466	-0.24740	
net value (post May 97)	-0.02235	-0.16935	-0.19170
Latitude, main cast			net value
Niño	0.00813	-0.00721	0.00092
Niño*D_May97	-0.02417	0.02321	
net value (post May 97)	-0.01604	0.01600	-0.00004

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[22] Only the 'Niño*T_Alta' sign changes in the model that explains the fishing cast parallel (now it is positive and statistically significative).

- Regulatory Changes

The regulatory regime RF decreases the average duration trip for vessels B1, while it increases the average duration trip for the other vessels categories (B2 and B3, the last with more force). The last mentioned is true respect to the previous regime of OR.

In terms of reported longitudes, under RF the fishing casts don't apperar to be performed in statistically different locations related to what in average happened under OR. With regard to latitudinal location of the casts, only vessels B3 present differences respect to OR period, since the casts associated to these vessels are in average further to the North.

In the case of Individual Quotas regime (IQ), it is obtained a higer increase in average trip duration (again related to OR). By other side, there are not effects over the average cast longitude, but there is a latitudinal location further to the North for vessels B3.

During the OR regime, increases in the jack mackerel abundance are associated with long trip duration, where vessels B3 have a duration trip significative inferior to the other two categories. As the resourse abundance increces, the fishing casts are located further to the North and further to the high seas. The last two effects grow with the size of the vessel. This is consistent with the different specializations standars in pelagic speaces fishing, according to the vessel size.

Wtih the new regimes introduction, RF and IQ, some changes are produced in the last mentioned effects (net effects in Table 5). Considering average effects over the hole fleet in operation, according vessel category, under OR an RF, there is an parcial positive asociation between resource abundance and trip duration; although this parcial association becomes negative for vessels B2 under IQ regime.

In terms of the reported longitudes, under RF there are not statistically significant differences in relation to OR period. With respect to the reported latitudes, only for vessels B3 the introduction of regimen RF and IQ produce significative impacts: while under OR the fishing casts are in average located further to the North for these vessels, under RF and IQ, the cast latitudinal location for vessels B3 was in average further to the South.

Table 5: Parcial Correlations. Change in Resourse Abundance (Average Net Effects Accordind Vessel Category an Regulatory Regime)

Regulatory Regime	Trip duration			Longitudinal distance (n. miles), main cast			Latitude, main cast		
	B1	B2	B3	B1	B2	B3	B1	B2	B3
OR	0.1185	0.1185	0.0792	0.2027	0.2617	0.2780	-0.0013	-0.0037	-0.0077
RF	0.4243	0.1324	0.1082	0.2027	0.2617	0.2780	-0.0013	-0.0037	0.0063
IQ	*	-0.1949	0.0792	*	0.2617	0.2780	*	-0.0037	0.0060

*: under IQ, there has been no operation of vessels type B1 (for catching j. mackerel).

- Other operacional features of the fleet.

With respect to a possible 'structural change' related to the increasing incorporation of cold storage capacity on board in the fleet under study, the estimation statistically significative results that are obtained are: Since 1990 and for the three vessels categories, the average duration trip increases and this effect is stronger as the vessels size grows. Moreover, the vessels B2 and B3 perform their fishing casts 'further to the high seas and further to the south'(versus before 1990), while the opposite effects are obtained for the smaller vessels. From the previous idea it could be inferred that since 1990 vessels B1 are concentred more in cost fishing (and therefore in sandiness and anchovies fishing) and further to the north, while the opposite happens for the rest of the vessel.

When the origin port (for each trip) is controlled (and with not differentiation about the vessel size), *under the OR regime* the next statistically significant effects are obtained: the trips with longest duration come from ports located in region VIII and those with shorter duration trip come from ports in X region. Likewise, the set sails from VIII and X regions report fishing casts in average nearer to the coast, compared with the reported information for those trips that come from ports in V region In relation to the main casts latitudes, the results are those expected a priori: set sails from VIII and X region are correlated with casts further to the south, versus the fleet that comes from V region.

In addition, when controls for new regulatory regimes RF and IQ are considered, the next net effects (statistically significative) are obtained, accordind to each set sail region:

(i) *Trip duration*: Under RF, the longest trips belong to vessels that come from ports located in V region and the shortest from X region. In the IQ regime, the longest average duration trips come from ports in the X region, and the shorter trips come from V region.

(ii) *Longitude* of the reported casts: Under the RF regime there are no differences in the longitudinal location of main fishing casts according to set sail regioin. In IQ regime, the trips with major longitude come from ports in X region, while those that come from VIII and X show in average a longitudinal location nearer to the coast.

(iii) *Latitude* of the reported casts: In this dimension and under de RF regime the highest average latitudes are reported in trips that come from ports located in V region while the smallest average latitudes belong to trips that come from VIII region. During the IQ regime there are not differences in the average latitudinal localization of trips according to set sail region.

The following table shows the estimated net effects, according to set sail region for each trip:

Table 6: Set Sail Región

Effect /Regulatory Regime	OR	RF	IQ
Major trip duration in…	VIII	V	X
Mayor longitudinal distance at which the main cast (per trip) is m	V	*	X
Major parallel at which the main cast is made per trip in …	X	V	*

(*) No difference

In relation to the variable that controls changes in "harvest by effort unity" according to the fishing zone, the next table resumes the net effects that were obtained:

Table 7: Harverst by effort unity

Periods/ Variables	Trip Duration	Longitude	Latitude
Before 1990	-0.01749	0.00852	0.00030
From 1990 until april 1997	-0.00010	0.02001	-0.00004
From may 1997 until december 2004	-0.00785	-0.03339	0.00024

Previous to year 1990, the zones with major"harvest by effort unity" [23] are related to casts reported with higher latitude and longitude, but with less average trip duration. Probably this kind of zones corresponds to trips that come from ports located further to the south (VIII and X regions)

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[23] Harvest per 'mile covered' in the duration trio equations and harvest per 'trip hour' in the other two equations

Since 1990 so far, the zones with higer "harvest by effort unity" in average are reported in coordinates with major longitude (even more than previous 1990), but now in latitudes further to the North, besides involving trips with major duration (respect to de average trip duration before 1990).

It is probable that this kind of zones be related to set sails from V región, trips that finally perform fishing casts so far from the coast (major longitude). This result could be a reflect of increasing cold storage capacity on board in fleet and, as a consequence, vessels have higer trip autonomy. The last is consistent with technological change that happened increasingly since earlys 1990.

6. Conclusions

Two types of results stand out as contributions emerging from the modeling performed. A first contribution is that, given the extent of the time-series dimension of the data used, it has been possible to analyze effects associated with the occurrence of El Niño events on fishing location in this fishery. The authors know of no previous studies on this type of effects in this or in other jack mackerel fisheries. The results obtained indicate that the El Niño phenomenon has indeed had effects on the fishing location decisions of this fleet. The sign and significance of the effects estimated are robust when considering contemporaneous effects as well as impacts with up to 6 months delay. The sign of the effects estimated varies according to the time of the year (fishing season) in which the El Niño phenomenon is current. On the other hand, it is not possible to reject the hypothesis that, as from May 1997, there has been a structural change, linked to the strong 1997-98 El Niño event, in the fishing location decisions of the fleet analyzed. This may be related with changes taking place in the densities and spatial distribution of different jack mackerel population nuclei, living and migrating between the Chilean EEZ and high seas neighboring areas.

A second area of contribution is related with effects associated to regulatory changes that have been implemented in this fishery, including the introduction of individual fishing quotas. Some of the effects associated with regulatory change vary their sign and/or statistical significance depending on the size category of the vessel operating. Also, regulatory-regime dependent effects are obtained as being associated to changes in fish abundance. Both kinds of results reflect the different fishing incentives (and restrictions) that prevail in one regulatory regime or another; and with these incentives differing according to the vessel's size category. The latter effect is a reflection of the different target species (fishing specialization patterns) that predominate in vessels with different sizes and autonomy at sea.

The estimation performed is a first exploratory effort to analyze aspects related to fishing location in this transboundary fishery. Now, and though the modeling of spatial decisions forms part of recent developments in econometrics, in the area of fishery economics we have cited applications that have modeled correlation structures between different fishing areas which form part of the set of choices to be optimized. We have also cited models related with information-sharing mechanisms between different fishing agents. Both lines of analysis represent challenges of interest for future research.

In the case of the fishery analyzed here, a probably more immediate priority of analysis is related with modeling and testing possible patterns of serial correlation in the residuals of the estimation model. This is motivated by the extent of the available data – particularly in its time series dimension – and also by the interest in analyzing effects associated with cyclical environmental processes, as in the case of the El Niño phenomenon.

Appendix 1: Allocation of 'target species' per fishing trip

In the fleet under analysis, mackerel (*scomber japonicus*) is a species that is caught as by-catch of jack mackerel, and there is no way to discriminate between one species and the other prior to the yield found in each cast. Given that, and because during the sampling period mackerel was not subject to catch quotas, which did occur with jack mackerel, the trips with the aim of fishing mackerel are also included in our estimation exercises.[24] Thus jack mackerel and mackerel are considered as a single species. Given that each trip's fishing intention is not observable, the following two criteria are used in this respect:

(a) Fishing intention for trips with nil catch in month t

With respect to these data, a new variable is calculated which identifies the catch of each species in the three immediately preceding trips and in the three immediately following trips; then the fishing total for each species in these adjacent trips is added. The 'fishing intention' in the trip with zero catch is attributed to the resource which has the greatest amount in the adjacent trips. This criterion enables 39,129 trips with 'zero catch' to be assigned to the set of trips with 'jack mackerel and/or mackerel' fishing intentions.

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[24] And this as a way of dealing with possible 'false report' events in which, given the current maximum catch quota for jack mackerel but not for mackerel, there may be incentives to make false reports, declaring as mackerel volumes of fish which really correspond to jack mackerel.

(b) Fishing intentions for trips in which one or more species is caught

To define the target species of trips with a positive catch of more than one species, it is considered that the fishing intention corresponds to resource k when the fishing of this resource, in a particular trip, is greater than the catch of any other.[25]

Appendix 2: Calculation of quotient (Fishmeal Price/Fuel Price)

Information on the fishmeal price is taken from the Banco Central de Chile (www.bcentral.cl). It is available in monthly terms from January 1987 and corresponds to the monthly average FOB price, expressed in US$/ton, considering the total of monthly shipments of fishmeal exports, which averages the price of the different qualities of fishmeal being exported.

For the fuel price variable, we used the monthly series provided by the Chilean Energy Commission of Diesel Fuel (type 2), which is what most of the industrial fishing vessels use (see www.cne.cl/estadisticas/), expressed in US$/liter. Given that this series is available only as from January 1991, a connection is made with the petrol import price series (available in www.bcentral.cl), replicating the price variations reported in the latter series during the period January 1987 to December 1990. The econometric estimation thus finally incorporates 18 years in the analysis (1987-2004).

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[25] In practice, trips with catches of 'jack mackerel and/or mackerel' do not occur together with 'sardine and/or anchovy' or Hoki (*macruronus magellanicus*). In our database, less than 0.2% of the total of trips with positive capture correspond to trips that report joint fishing of 'jack mackerel/mackerel' and of 'sardine/anchovy'.

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