ICES Journal of
Marine Science

ICES Journal of Marine Science (2014), 71(3), 628–635. doi:10.1093/icesjms/fst186

Original Article

An econometric analysis of the Spanish fresh fish market

José I. Castillo-Manzano[1]*, Lourdes López-Valpuesta[1], Fernando Gonzalez-Laxe[2] and Diego J. Pedregal[3]

[1]*Applied Economics & Management Research Group, University of Seville, Avda. Ramón y Cajal, 1, 41018 Seville, Spain*
[2]*University of A Coruña, A Coruña, Spain*
[3]*University of Castilla-La Mancha, Ciudad Real, Spain*

**Corresponding author: tel: +34 954 55 67 27; fax: +34 954 55 76 29; e-mail: jignacio@us.es*

Castillo-Manzano, J.I., López-Valpuesta, L., Gonzalez-Laxe, F., and Pedregal, D. J. 2014. An econometric analysis of the Spanish fresh fish market. – ICES Journal of Marine Science, 71: 628–635.

Received 22 May 2013; accepted 5 October 2013; advance access publication 14 November 2013.

This article seeks to analyse the factors that determine the dynamics of the balance between supply and demand in the Spanish fresh fish market. For this, the time-series of fresh fish landed in the 1973–2009 period is analysed through an estimation of the series of transfer function models. Among other things, the findings in the Spanish case show a complex relationship between the amount of fish landed and price; a clear substitution relationship between fresh fish and aquaculture; a negative impact of labour costs in a manual labour-intensive sector such as fishing, which in developed countries is being affected by an exodus of manpower to other sectors where there is less uncertainty surrounding labour conditions; the impact of Spain being barred from international fishing grounds a result of the delimitation of exclusive economic zones (EEZs); and the dwindling importance of fisheries traffic as a result of the port devolution process begun in Spain in the early 1990s. The non-significance of *a priori* key factors, such as the price of oil and Spain's entry into the EEC, can be explained by widespread energy subsidies and contradictions in the objectives of the Common Fisheries Policy, respectively.

Keywords: aquaculture, fresh fish market, frozen fish, transfer function models.

Introduction

Improvements in fishing technology (Anticamara *et al.*, 2011; Sinclair *et al.*, 2002) and a growing demand for fish have been the major drivers of the increased fishing effort (Arnason *et al.*, 2009) that has resulted in the overfishing of fishing grounds. The figures are conclusive. According to the FAO (2012a) report, in 2009, 57.4% of marine fish stocks were fully exploited, 29.9% overexploited, and only 12.7% were non-fully exploited.

Although fishing is considered the greatest single cause of the depletion of global fisheries (Arnason *et al.*, 2009), other environmental factors, such as climate change (Grafton, 2010), pollution, and the detrimental impacts of contaminants on fishery ecosystems, the destruction of critical habitats, invasive species, and mineral extraction, have also resulted in a decline in catches (Arnason *et al.*, 2009).

As with any overexploited economic activity with growing demand, the most evident economic consequences are low profitability (Helstad *et al.*, 2005; Arnason *et al.*, 2009), increases in the prices of fish resources (Jiang, 2010), and the need to regulate the level of the fishing effort (Fousekis *et al.*, 1999) and to reconvert a sector with an oversized fishing fleet (Sinclair *et al.*, 2002). At the same time, the nutritional effect of overfishing and a growing population will be a fall in the annual *per capita* availability of fish. Up to now, the fish supply has grown at a greater rate than the population [3.2% annually compared with 1.7% annually, respectively, from 1961, according to the FAO (2012a) report]. Nevertheless, the decline in wild fish stocks is a threat to food security (Jiang, 2010). This problem is even more serious in areas where fish is the most important renewable resource and contributes substantially to subsistence (Bell *et al.*, 2009).

There have therefore been major changes in the global demand for and supply of fish in recent decades (Dey *et al.*, 2005) and, given these circumstances, the factors that govern the balance between fresh fish supply and demand need to be examined and any factors that affect future growth determined.

In our specific case, we have analysed the time-series of fresh fish landed in Spanish ports of general interest during the 1973–2009 period. The Spanish case is especially relevant bearing in mind the economic importance of the Spanish fisheries market. In 2009, annual *per capita* consumption of fish in Spain stood at 43.2 compared with 18.4 kg worldwide. Spain ranks second only to Portugal in fish consumption among the EU member States (FAO, 2012b), and in 2010, it was the third largest importer of fish products in the world behind the United States and Japan (FAO, 2012a).

The Spanish fisheries sector is very heterogeneous and extremely atomized around the country's lengthy coast. A variety of fishing modes coexist (small scale/artisanal, inshore, coastal, and industrial) with a range of organizational formulae likewise existing alongside each other. Most companies are located at base ports and fish in a certain area, although their fishing modes and the areas where they operate may vary throughout the year. Meanwhile, as far as inter-port competition is concerned, the Spanish port system is the result of a series of legal reforms that began in 1992 (see Castillo-Manzano *et al.*, 2008). These reserve the control of general interest ports, where fisheries traffic is found alongside other commercial traffic, from goods to passengers, for the central administration. Ports with fisheries traffic, highly localized commercial traffic, and recreational ports and marinas are the responsibility of the regional governments (the so-called Autonomous Communities).

This patchwork of specifications gives rise to many peculiarities. To avoid analysing each of these, we have analysed the landings of fresh fish channelled through the general interest ports. The choice of these ports is also justified by their greater importance for both the supply and demand of fresh fish. First, these ports are usually located in provincial capitals or the provinces' most-populated cities which means that they are the largest markets for fresh fish demand due to their proximity. Second, a large part of the supply from small ports in the area is also channelled through these ports with a view to achieving greater economic value from the supply and easier distribution to the rest of Spain. As a result, the state-owned fish distribution company (MERCASA) has branches at the general interest ports but not at the smaller ports.

There is a wide range of determinants, ranging from the development of alternatives to fresh fish, such as aquaculture and frozen fish, to the cost of production factors that condition fish supply and institutional factors that determine the political and economic framework in which the activity is conducted.

Regarding the alternatives to fresh fish, aquaculture production plays a major role in the supply of fish for human consumption, constituting 46.7% of total fish food supply in 2008 (FAO, 2012a). While output from capture fisheries has remained stable, overall fish production continues to rise due to aquaculture (Hannesson, 2003). Aquaculture is therefore expected to determine how fisheries grow in the future to a large extent and advances in aquaculture technology could play a key role in restoring fish stocks (Jiang, 2010). However, the potential of aquaculture may be restricted by a number of issues, mainly connected with the environmental damage that it produces and the availability of feed fish (Hannesson, 2003).

In other respects, fish is increasingly being traded as a frozen foodstuff (39% of fish sold in the world in 2010 compared with 25% in 1980), while the trading of live, fresh, and chilled fish was only 10%, reflecting improved logistics and increasing demand for unprocessed fish (FAO, 2012a). For Vanhaecke *et al.* (2010), the success of freezing as a processing method can be explained by its ability to preserve an otherwise highly perishable product. Frozen fish also has some advantages over fresh fish. First, while growing demand for fish is putting up prices (Jiang, 2010), frozen fish enables consumption to be generalized at a lower price. Given the very inelastic supply of fresh fish in the short term (Barten and Bettendorf, 1989), the sharp rise in demand has had an effect on price. Generally speaking, on average, fresh fish is priced higher in the market than frozen fish (Trondsen, 1997). Growing concern for health risks associated with fresh fish might result in a market shift towards frozen fish, as it provides certain benefits appreciated by consumers who feel less certain about fish quality and safety (Vanhonacker *et al.*, 2010). In contrast to these positive aspects, many consumers perceive frozen fish to be of worse quality (Merritt, 1982; Brunsø *et al.*, 2009) and less nutritious than fresh fish (Peavey *et al.*, 1994).

Other factors that might affect the quantity of fresh fish landed and traded are the current and past prices of fresh fish (a subject analysed in the literature, e.g. in Barten and Bettendorf, 1989 and Ioannides and Whitmarsh, 1987) and the inputs that determine the fishing effort, which Fousekis *et al.* (1999) indicated are energy—mainly fuel—labour costs, and capital. We focus on the first two of these as, following Arnason *et al.* (2009), although fishing costs vary greatly by type of fishery and locality, in general, the major cost factors for most fisheries are labour and fuel (see also Lam *et al.*, 2011, on the importance of these two factors for total cost in the FAO regions).

Fuel continues to be a major cost in the catching sector and although it currently varies by fishery as a proportion of overall costs, it can reach up to 60% in some cases (Sumaila *et al.*, 2008). Progressively, increasing fuel prices are fixed costs that are leading to a significant loss of income, reduced job security, and problems with recruiting crew (Abernethy *et al.*, 2010). What is more, as Suuronen *et al.* (2012) state, most of the fishing techniques currently used come from times in the past when energy costs were dramatically lower than current levels. Only from the 1970s oil crisis onwards, has energy saving become a topic for research aimed at improving vessel design and power consumption (Parente *et al.*, 2008). As fossil fuels currently cannot be replaced as the source of power in fishing vessels (Suuronen *et al.*, 2012), we have taken the price of oil into account as a factor that determines the amount of fresh fish.

Labour conditions in the fisheries sector are special and for this reason, they have also been taken into account and included in our model of determinants of the amount of fish landed. This is a sector characterized by a lack of both regular employment and a stable income and is faced with falling employment due to modernization, economies of scale, and the substitution of capital for labour (Symes and Phillipson, 2009).

Other factors that may also have affected the fresh fish supply in Spain during the period analysed were Spain's adherence to the Common Fisheries Policy (CFP) after the country joined the EEC, the negotiations that took place before, and the subsequent reforms of the Common Policy; the delimitation of exclusive economic zones (EEZ), and Law 27/1992, concerning State Ports and the Merchant Navy, which favoured a port devolution process for the ports considered in this analysis (see Castillo Manzano *et al.*, 2008, 2010a, b for a detailed analysis of this law and its effects on the Spanish port system).

The causality chosen in this paper has to be justified, since this topic has a long tradition in the area (see, for example, Kabir and Ridler, 1984; Barten and Bettendorf, 1989; Burton and Young, 1992; Eales *et al.*, 1997; Westlund, 2005; Nielsen, 2009; Nielsen *et al.*, 2009), where some authors consider the relation to be from prices to quantity, but often the inverse relation is considered as more appropriate. The causality in the Spanish case is considered from prices to quantity because of the time-scale, the sampling interval of the available data (yearly), and the fact that the topic is peculiar in this case, because although Spanish prices might be considered endogenous on the national scale, in practice they are considered to be exogenous because of the strong pressure of worldwide prices in the Spanish market. The topic of exogeneity of prices is carefully taken into account in the Results section via several statistical tests.

Using the estimation of a series of transfer function models in the tradition of Box *et al*. (1994), we shall therefore seek to analyse the determinants of the amount of fresh fish. The proposed methodological approach enables us to go beyond a simple descriptive view of this relationship. To be precise, this methodology allows us to carry out a dynamic analysis that exploits the time-series structure of the port traffic series.

One of the main strengths of this study is its broad sample, from 1973 to 2009, which nonetheless also imposes some major restrictions. Basically, given the breadth of the sample, there are no time-series for many of the variables that could be used as explanatory variables in the Spanish case. In this respect, unlike fresh fish, there is no indicator available for the price of frozen fish. The same is true for the series for capital used in the fisheries sector. This problem is overcome methodologically by including a broad autoregressive term which enables the coefficients of the variables included to be corrected for any omitted variables bias.

The article is organized as follows. The Data and methodology section presents the data and the methodological approach. The Results section presents the empirical findings, and the Discussion and conclusions section sets out the conclusions of the study.

Data and methodology

One of the model's strengths is the use of primary data from a variety of statistical sources as this makes it easy for other researchers interested in the topic to reproduce the empirical results.

The dependent variable in our model is the amount of fresh fish landed at Spanish general interest ports between 1973 and 2009 (data obtained from *Puertos del Estado*, the Spanish National Ports and Harbors Authority, http://www.puertos.es/en). The Spanish ports considered in this analysis are the 46 ports of general interest under the administrative control of the Central Government. Fishing ports under the jurisdiction of regional governments have been excluded. Apart from the justification given for this choice in the introduction, it is also justified by the continuity of fishing statistics for general interest ports from 1973, which provides us with a very long time horizon. The independent variables were therefore conditioned by the length of the time-series of the dependent variable. The following were included.

(i) The price of fresh fish taken from *Puertos del Estado* statistics. According to economic theory, price is a basic factor that determines the amount of supply and, *a priori*, a negative relationship is to be expected between the amount of fish landed and the price.

(ii) Substitute commodities such as the amount of frozen fish landed at the general interest ports (data obtained from *Puertos del Estado*), the imports of fishery commodities by Spain, and aquaculture production in Spain (data for the last two obtained from FAO, www.fao.org.fishery.stadistics).

Of these three series, aquaculture can be considered to be the substitute commodity closest to the fresh fish landed, so a negative effect should be expected on aquaculture, implying that increasing aquaculture (ceteris paribus) means less native fishing activities. As for frozen fish, *a priori* it is difficult to determine whether this coefficient will be positive or negative. It could be negative if people's predilection for fresh fish is considered to lead to a fall in the demand for frozen fish or *vice versa*. Or, it could be positive if the supply of frozen fish increases at the same time as the supply of fresh fish; this would clearly signal an overall growing demand for fish in Spain, in short, a predatory model that would not be sustainable. Finally, the coefficient could also have a value that is not significantly different from zero, in which case, we would be talking of fresh fish and frozen fish as two distinct and separate commodities. The coefficient associated with imports can be interpreted in the same way.

(iii) The main production inputs, such as energy costs [price of a barrel of Brent oil taken from the BP Statistical Review of World Energy 2012 and unit labour cost [INE (the Spanish National Statistics Institute) and the Ministry of Economics and Finance Macroeconomic Analysis General Sub-directorate]. Although these variables are not specific to the fisheries sector, they have been chosen because of the length of the time-series of the dependent variable. Unfortunately, as is well known, information on the cost of fishing is scarce and incomplete in Spain, as it is most countries and regions in the world (see Lam *et al*., 2011).

As stated in the Introduction section, the cost of fuel has risen substantially for the fishing industry over the last 40 years due to both mechanization and the greater distances between fishing grounds and fishing ports (Suuronen *et al*., 2012). This is therefore an indispensable requirement for the sector which can have a bearing on its future growth and, consequently, on production in the sector. As a result, *a priori* a negative coefficient can be expected when estimating the model.

With regard to unit labour cost, as before a negative relationship is to be expected as any increase in the cost of production would result in a fall in supply. Moreover, if we take the general unit labour cost of the economy as an indicator of the working population's standard of living, any increase would be an incentive for a transfer of employment from extractive sectors in the economy to other sectors with less severe working conditions, fewer work accidents, and less precariousness. In short, an increase would be an indication that the opportunity cost of being a fisher rises compared with other activities, and as a result also has a negative influence on the volume of fresh fish.

(iv) Institutional factors that stand out in the yearly series considered, such as:

(a) Restrictions imposed on the Spanish fleet during the pre-accession period from 1977 to 1986 that resulted in a loss of markets and fleet.

(b) Delimitation of EEZ from 1982, which involved the change of the 200 miles of coastal waters to coastal jurisdiction.

(c) Spain's accession to the EEC in 1986 with the consequent implementation of the CFP.

(d) The reform of the CFP in 1992 and the Spanish port system's port devolution process that began with Law 27/1992 of the same year.

All of these are included in the model as step-type dummy variables.

It is difficult to speculate on the possible direction and significance of some of these variables. With regard to limits on access to fisheries resources imposed by the EEC before Spain's accession in 1986 and subsequently due to the delimitation of EEZ, it seems logical to expect that they will have a negative effect on the amount of fresh fish landed. On the other hand, we could expect Spain's joining the then EEC to have had a positive effect due to many amounts of aid received from community funds, although for Spain, it also involved successive rounds of negotiations between the European Commission and third countries to finalize fishing agreements. These would contain the clauses and trade-offs that would facilitate the access of Spanish vessels to these countries' EEZ, and the conditions imposed on the importation of fish products, including customs duties and quotas applicable to EU countries, once the Common Organization of Markets was passed.

Finally, 1992 was important for two events. First, there was the 1992 reform of the CFP, which did not improve the Treaty of Accession for Spain in terms of fisheries affairs. In other words, the discriminatory situation regarding conditions of access to certain fishery areas in EU waters, the way that fishing quotas were distributed among countries, and the demand for the Spanish fishing fleet to be subject to a licensing system all remained (González-Laxe, 1992). Second, Law 27/1992, which marks the beginning of the port devolution process in Spain and is one of the most studied in all the world (see Suárez de Vivero *et al*., 1997; Castillo-Manzano and Asencio-Flores, 2012), was passed. Castillo-Manzano *et al*. (2010b) maintain that ports used this autonomy to develop strategies and make large-scale investments to attract other traffic, such as containers, while paying little attention to fisheries traffic or making efforts to divert it to regional ports exclusively used for fishing. The complexity of this variable due to the two events coinciding means that it is *a priori* difficult to speculate in any way on the value and arithmetical sign of its coefficient. Because of this, and also because the individual contribution made by the two reforms cannot be separated methodologically, the value of this coefficient will measure the net effect of the two overlying reforms.

(v) Other factors determining fish supply that have not been explicitly modelled are the fish populations; the reproductive biomass (fertile females); and the specific features of the environment, such as water temperature, salinity, currents, and pollution, as well as those specific to the product itself, such as its perishability. To capture the effects of these variables and any others not directly included, we have added a noise model with autocorrelation that resulted in a second-order autoregressive structure (see below). This also avoids specification problems in the estimation of the models.

The time-series models employed in the analysis are in the class of discrete time linear transfer function models (Box *et al*., 1994) for the cyclical or the short-term data, i.e. the first differences of the data in logarithms. This is an approximation of the annual rate of change. The general formulation may be expressed as:

$$y_t = \sum_{j=1}^{h} F_j(B) u_{j,t} + N(B) e_t, \qquad (1)$$

where y_t is the cyclical fresh amount per population; $u_{j,t}$ are the above inputs on which the output data depend; e_t is a zero mean and constant variance Gaussian white noise; $F_{i,j}(B)$, $(j = 1, \ldots, h)$, are ratios of polynomials in the backshift operator (i.e. $B^k y_t = y_{t-k}$). All transfer functions except one collapse to linear regression terms, i.e. the only significant terms are those corresponding to the term in lag 0, B^0. The exception is the term for the fresh fish price, which is a polynomial of order 1 (Table 4). The general representation of the noise model $N(B)e_t$ in (1) is identified empirically as constrained AR(2) models in the below equation. The models are estimated by exact maximum likelihood with the aid of the ECOTOOL Matlab toolbox (Pedregal and Trapero, 2012).

$$N(B)e_t = \frac{1}{(1 + a_1 B + a_2 B^2)} e_t. \qquad (2)$$

We performed the following diagnostic tests of residuals to test the robustness of the model:

(i) The Schwarz Bayesian Criterion (SBC) test is a measure that combines fit with parsimony in a single formula

$$SBC = -2 \ln L + k \ln(n),$$

where $SBC = -2 \ln L + k \ln(n)$ is the likelihood at the optimum, k the number of parameters in the model, and n the length of the sample. The smaller the SBC, the better. Good fit (i.e. high L) is balanced by the number of parameters.

(ii) Ljung–Box test Q is a portmanteau test for autocorrelation. The test statistic is based on the h first autocorrelations of residuals

$$Q = n(n+2) \sum_{k=1}^{h} \frac{\hat{\rho}_k^2}{n-k},$$

where $\hat{\rho}_k$ is the autocorrelation of order k estimated on the residuals. The critical region is based on a χ_h^2 distribution with h degrees of freedom under the null hypothesis of no autocorrelation. High values of Q imply correlated noise.

(iii) The Jarque–Bera (JB) gaussianity test is a test based on the skewness (S) and kurtosis (K) of the residuals. The statistic is defined as

$$JB = \frac{n}{6}\left(S^2 + \frac{1}{4}(K-3)^2\right).$$

The JB is asymptotically distributed as a χ^2 with two degrees of freedom under the null hypothesis of gaussianity. High values of the statistic imply non-gaussian noise.

Table 1. Unit root tests on log variables in a logarithmic scale.

Variables	ADF constant	ADF trend stationary	PP constant	PP trend stationary
Amount of fresh fish	−0.4780 (0.8829)	−1.6691 (0.7339)	−0.6314 (0.8508)	−1.9909 (0.5854)
Price of fresh fish	−1.8026 (0.3819)	−2.0953 (0.5363)	−2.0715 (0.2673)	−2.2639 (0.4584)
Amount of frozen fish	−1.4108 (0.5484)	−1.6677 (0.7338)	−0.9841 (0.7314)	−4.2982 (0.0090)
Imports	−0.907 (0.7151)	−2.389 (0.413)	−1.574 (0.479)	−1.644 (0.7465)
Aquaculture	−1.525 (0.4962)	−1.921 (0.5956)	−2.465 (0.1326)	−2.702 (0.2543)
Energy costs	−1.2984 (0.5965)	−1.7050 (0.7172)	−1.2614 (0.6130)	−1.8210 (0.6645)
Per-unit labour cost	−1.7508 (0.4038)	−1.9446 (0.6057)	−1.3367 (0.5806)	−1.9765 (0.5917)

ADF stands for augmented Dickey–Fuller test. PP stands for Phillips–Perron test. Null is that each time-series is not stationary. *p*-values are in parentheses. The lags for each model are identified automatically according to the AIC2 criterion in Pantula *et al.* (1994).

Table 2. Unit root tests on first differences of variables in the logarithmic scale.

Variables	ADF constant	ADF trend stationary	PP constant	PP trend stationary
Amount of fresh fish	−2.8038 (0.0691)	−2.7978 (0.2112)	−5.7410 (0.0010)	−5.6724 (0.0010)
Price of fresh fish	−2.8774 (0.0594)	−2.8234 (0.1996)	−4.6213 (0.0010)	−4.5564 (0.0048)
Amount of frozen fish	−4.0855 (0.0040)	−4.3435 (0.0088)	−10.8751 (0.0010)	−11.1016 (0.0010)
Imports	−3.215 (0.0301)	−4.222 (0.0120)	−6.528 (0.0010)	−6.871 (0.0010)
Aquaculture	−2.903 (0.059)	−3.336 (0.0808)	−6.357 (0.0010)	−6.281 (0.0010)
Energy costs	−2.8255 (0.0661)	−2.7774 (0.2206)	−5.5797 (0.0010)	−5.4652 (0.0010)
Per-unit labour cost	−3.6389 (0.0103)	−4.8740 (0.0030)	−9.6789 (0.0010)	−4.5536 (0.0048)

As in Table 1.

Table 3. Granger non-causality tests and Hausman exogeneity test.

Null	Statistic	*p*-value
Granger: quantity does not cause price	1.093	0.341
Granger: price does not cause quantity	5.609	0.006
Hausman: price is exogenous	5.909	0.879

The reference model for the Granger tests is the VAR(2) model identified via the SBC. The Hausman test is based on a two-stage estimation of the model in Table 4, taking the noise-free price output in VAR(2) as an instrumental variable of the fresh fish price.

Results

The first stage consists of an exploratory analysis of the data to check the degree of integration. The well-known augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests are shown in Tables 1 and 2, with the assumption that the series are both difference and trend stationary. The results show without any doubt that all series are integrated of order 1. This is the main reason why the models are estimated in first differences.

Two tests were performed on the data to verify whether the unidirectional causal relationship implied by the model outlined in the previous section is correctly specified. First, a Granger non-causality test based on a VAR(2) model identified by the SBC on the fresh fish amount and price time-series (see Lütkepohl, 2005, for details). These tests clearly demonstrate that the causality direction runs from prices to quantity and that there is no feedback (Table 3).

Second, a Hausman test of exogeneity of prices in the equation was run to check the specification correctness of the causal relationship (see, for example, Greene, 2011). Demand-like equations similar to the equation in this paper usually suffer from miss-specification due to the correlation between the perturbation and fresh fish price induced by the fact that the "true" system consists of both a demand and a supply equation (see, for example, Stock and Watson, 2010). Hausman tests basically consist of a comparison between the estimates of the equation shown in Table 4 and "two-stage" estimations obtained by replacing the fresh price input in the Table 4 model with the "noise-free" input taken from the second equation of the VAR(2) model used for the Granger tests. In essence, this "noise-free" input is a valid instrumental variable for the price taken as an input in either the first equation of VAR(2) or the model in Table 4, since said instrumental variable is highly correlated with price and at the same time is uncorrelated with the perturbation of the quantity equation by construction. These "two-stage" estimates are consistent, even when the inputs are endogenous, while the estimates in Table 4 would be consistent only if the price input is exogenous. Therefore, with a Hausman test null (i.e. price is an exogenous variable), there should be no great differences between the two estimators.

The results in Table 3 show unequivocally that causality runs in the assumed direction and that price is effectively an exogenous variable.

Table 4. Estimation results.

Independent variables	Dependent variable: amount of fresh fish
Price of fresh fish	(−0.985***+0.13**B)
Amount of frozen fish	0.087
Imports	−0.006
Aquaculture	−0.092**
Energy costs	−0.0015
Per-unit labour cost	−0.186***
Pre-accession EEC 1977	−0.006
EEZ 1982	−0.027**
Accession EEC 1986	0.046
1992 CFP Reform and Law 27/1992	−0.040***
AR(1)	0.938***
AR(2)	0.582**
R2	0.797
σ^2	1.292 × 10−3
SBC	−5.167
Q(1)	0.120
Q(4)	1.587
JB	2.367 (0.31)

Two and three asterisks indicate coefficient significance at the 5 and 1% levels, respectively. σ^2 stands for the innovations variance; SBC is the Schwarz Bayesian Criterion; Q(1) and Q(4) are the Ljung–Box Q statistics for 1 and 4 lags, respectively; JB is a Jarque–Bera gaussianity test (*p*-values in parentheses).

Table 4 shows the estimated parameters of the final model. The endogenous variable is the short-term data for fresh fish in Spain. The exogenous input variables are listed in rows, and include two blocks: (i) input variables, and (ii) parameters of the AR(2) model. A final block includes the additional diagnostic tests of residuals to verify model appropriateness.

It can be concluded from Table 4 that we have a set of statistically significant determinants that enable us to explain fresh fish transactions at Spanish ports of general interest. The significance of the price of fresh fish at the fish auctions, both for the current period (at 1%) and the previous period (at 5%), should be highlighted. Also significant are the unit labour cost, the 1992 political reforms, aquaculture production, and the limitations on access to fisheries resources caused by EEZs. The first two variables are significant at 1%, while the last two are significant at 5%.

Discussion and conclusions

The main objective of our study was to seek to explain the trade of fresh fish in the fresh fish market in the Spanish port system. The findings in Table 4 provide some conclusions in this respect of which the following stand out.

First, the relation between the price and the amount of fresh fish is quite complex. The price reached at auction by fresh fish is negatively related to the availability of the fresh fish that is landed during the period. But it is also noticeable that the coefficient for the previous year is statistically significant and positive, which confirms that the prices for the previous period have a positive influence on fish supply for the following period.

With respect to the production factors analysed, as expected the negative significance of the labour cost at 1% stands out. This could be justified in two ways; first, the greater the costs, the lower the production of a product as labour-intensive as fresh fish. On the other hand, as we used the general labour costs found in the economy, this result can be interpreted as an indicator of the drain of employment away from the catching sector to other professions where the working conditions are less severe and a worker's ability to produce income is not subject to the risks and uncertainties associated with seasonality, severe weather, fluctuations in stock, and the market instability found in the fishing sector (Symes and Phillipson, 2009). This is in keeping with Arnason *et al*. (2009), who stated that the decline in employment in the fisheries sector in the most developed countries can be attributed to relatively low remuneration linked to working conditions that are often high risk and difficult. In Spain, specifically, this displacement effect was seen to peak during the previous decade's strong economic development, which was mainly based on the construction industry (Wigren and Wilhelmsson, 2007). Construction work offered significantly higher wages to fishers without requiring high levels of education. It should therefore come as no surprise that, according to the Spanish National Statistics Institute, there was a constant reduction in the number of workers in the primary fisheries sector throughout the previous decade, with a fall from almost 55 000 in 2002 to fewer than 38 000 in 2010. This is especially significant given that these data include employment in aquaculture.

In other respects, as stated in the preceding section, a negative coefficient was to be expected for oil prices, as any increase in fuel prices would automatically reduce the amount of fish caught. However, although it is negative, the non-significance of the oil cost coefficient can be attributed to both the modernization of the fleet, with more energy-efficient vessels (on the European level, the modernization of the fleet favoured by the European Commission's multiannual guidance programmes has been questioned by the Court of Auditors itself, as an increase in vessel power has had an effect on both the fishing effort and led to a greater consumption of fuel) and the widespread policy of governments subsidizing fuel to guarantee the viability of the fisheries sector. These subsidies, influenced primarily by political and social concerns, can reduce, if not completely cancel out the negative effect that the rise in oil prices has on production (Sumaila *et al*., 2008), while they could also harm the above-mentioned process of more energy-efficient fishing. These subsidies therefore also preclude the proposed relationship in our model between fresh fish production and the cost of oil. For all these reasons, the above-described coefficient's lack of significance should come as no surprise.

With respect to substitute commodities, the significance of aquaculture, with its expected negative sign, stands out. Aquaculture offers more competitive prices and greater availability, as it does not depend on conditions of access or the share of fishing quotas or seasonality. Aquaculture products therefore become clear substitutes for fresh fish. In a country that is as dependent on fish as Spain, this role as a substitute is driving the sector up. To be precise, Spain is the leading country in aquaculture production in the EU (FAO, 2012b). But perhaps the most surprising finding is that there is no relationship between fresh fish and frozen fish. It can therefore be concluded that the two are independent markets, with products that are perceived as differentiated by producers and consumers alike. Frozen fish products can be bought to order as they have prolonged fishing seasons with information available on the catches that have been taken by the boat; the opposite is true of fresh fish products, which fluctuate more, have shorter seasons, and whose prices are therefore set on land once the product has been brought ashore. This supposed differentiation is also explicitly reflected in both EU and Spanish legislation that obliges the two products to be differentiated between in the end market. Fresh fish and frozen fish have to be located in different areas of commercial establishments for the consumer to be able to differentiate between them with no chance of error. It is also striking that imports do not impact on the amount of fresh fish landed, although the explanation might lie in the fact that they include a heterogeneous series of fish products that includes live, fresh, frozen, and chilled fish, many of which are not regarded as substitutes by the consumer.

Finally, the institutional factors throw up very mixed results. On the one hand, the delimitation of the EEZs had a clear negative effect on the amount of fresh fish landed in Spain (Garza-Gil *et al*., 1996). Before the EEZs were implemented, the Spanish fishing sector worked a large number of fishing grounds. Accepting the new international regulations meant hefty restrictions on access had to be borne. To be precise, Spain was affected with restrictions in fishing grounds such as Boston, Canada-NAFO, Morocco, and Mauritania. Meanwhile, neither negotiations before Spain's accession to the EEC nor the country's official entry in 1986 had any significant effects on Spanish fisheries according to our model. The lack of significance of Spain joining the EEC can be explained by the controversy over the CFP regarding both the contradictions in its aid for reducing the size of the fleet (Hatcher, 2000) and its possible adverse effects for Spain (González-Laxe, 2010).

These adverse effects may have been felt at a later date, as is shown by the negative change in the series from 1992 on. This year is especially significant both for the CFP reform and for signalling the beginning of the port devolution process in Spain. The negative significance of the legal changes in 1992 shows that the two changes had a joint negative net effect in Spain. This would confirm the hypothesis that the 1992 CFP reform was a missed opportunity for overcoming the conditions that were imposed by the Treaty of Accession and did not bring about full fisheries integration, with differences remaining in the distribution of quotas and in the behaviour of EEC members (Surís-Regueiro *et al*., 2003). Second, with the autonomy that they gained at the beginning of the port devolution process, the Spanish ports of general interest have targeted their management at other types of traffic and port activities that are, *a priori*, more profitable and less conflictive than fisheries traffic, including container traffic and the development of nearby logistics areas, while fisheries traffic has gradually been transferred from these ports to regional ports that do not form part of the general interest network.

Acknowledgements

The authors are grateful to Professor Dr Mitsutaku Makino and the two anonymous reviewers for their very helpful comments. The authors would also like to express their gratitude to the Ente Público Puertos del Estado for its financial support.

References

Abernethy, K. E., Trebilcock, P., Kebede, B., Allison, E. H., and Dulvy, N. K. 2010. Fuelling the decline in UK fishing communities? ICES Journal of Marine Science, 67: 1076–1085.

Anticamara, J. A., Watson, R., Gelchu, A., and Pauly, D. 2011. Global fishing effort (1950–2010): trends, gaps, and implications. Fisheries Research, 107: 131–136.

Arnason, R., Kelleher, K., and Willmann, R. 2009. The sunken billions: the economic justification for fisheries reform. World Bank and FAO.

Barten, A. P., and Bettendorf, L. J. 1989. Price formation of fish. An application of an inverse demand system. European Economic Review, 33: 1509–1525.

Bell, J. D., Kronen, M., Vunizea, A., Nash, W. J., Keeble, G., Demmkea, A., Pontifex, S., *et al.* 2009. Planning the use of fish for food security in the Pacific. Marine Policy, 33: 64–76.

Box, G. E. P., Jenkins, G. M., and Reinsel, G. C. 1994. Time Series Analysis Forecasting and Control, 3rd edn. Prentice-Hall, Englewood Cliffs.

Brunsø, K., Verbeke, W., Olsen, S. O., and Jeppesen, L. F. 2009. Motives, barriers and quality evaluation in fish consumption situations. Exploring and comparing heavy and light users in Spain and Belgium. British Food Journal, 111: 699–716.

Burton, M., and Young, T. 1992. The structure of changing tastes for meat and fish in Great Britain. European Review of Agricultural Economics, 19: 165–180.

Castillo-Manzano, J. I., and Asencio-Flores, J. P. 2012. Competition between new port governance models on the Iberian Peninsula. Transport Reviews, 32: 519–537.

Castillo-Manzano, J. I., Florido-del-Corral, D., and López-Valpuesta, L. 2010a. Fisheries traffic: the poor relation of port devolution. Lessons from Spanish State ports of general interest. Marine Policy, 34: 189–192.

Castillo-Manzano, J. I., López-Valpuesta, L., and Gonzalez- Laxe, F. 2010b. Political coordination costs in the Spanish port devolution process: a note. Ocean & Coastal Management, 53: 577–580.

Castillo-Manzano, J. I., López-Valpuesta, L., and Perez, J. J. 2008. Economic analysis of the Spanish port sector reform during the 1990s. Transportation Research A: Policy and Practice, 42: 1056–1063.

Dey, M. M., Briones, R. M., and Ahmed, M. 2005. Disaggregated analysis of fish supply, demand, and trade in Asia: baseline model and estimation strategy. Aquaculture Economics & Management, 9: 113–139.

Eales, J., Durham, C., and Wessels, C. 1997. Generalized models of Japanese demand for fish. American Journal of Agricultural Economics, 79: 1153–1163.

FAO. 2012a. The state of world fisheries and aquaculture. FAO Fisheries and Aquaculture Department, Rome.

FAO. 2012b. Fishery and Aquaculture Statistics Yearbook 2010. FAO Fisheries and Aquaculture Department, Rome.

Fousekis, P., Daouli, A., and Demoussis, M. 1999. The internal structure of effort in Greek fisheries: an empirical analysis. Fisheries Research, 41: 213–219.

Garza-Gil, D., Iglesias-Malvido, C., Suris-Regueiro, J. C., and Varela-Lafuente, M. M. 1996. The Spanish case regarding fishing regulation. Marine Policy, 20: 249–259.

González-Laxe, F. (coord.) 1992. La revisión de la Política Pesquera Comunitaria: el reto de 1992. Fundación Barrié de la Maza, A Coruña.

González-Laxe, F. 2010. Dysfunctions in common fishing regulations. Marine Policy, 34: 182–188.

Grafton, R. Q. 2010. Adaptation to climate change in marine capture fisheries. Marine Policy, 34: 606–615.

Greene, W. H. 2011. Econometric Analysis, 7th edn. Prentice-Hall, New Jersey.

Hannesson, R. 2003. Aquaculture and fisheries. Marine Policy, 27: 169–178.

Hatcher, A. 2000. Subsidies for European fishing fleets: the European Community's structural policy for fisheries 1971–1999. Marine Policy, 24: 129–140.

Helstad, K., Vassdal, T., Trondsen, T., and Young, J. A. 2005. Price links between auction and direct sales of fresh and frozen fish in north Norway (1997–2003). Marine Resource Economics, 20: 305–322.

Ioannides, C., and Whitmarsh, D. 1987. Price formation in fisheries. Marine Policy, 11: 143–145.

Jiang, S. 2010. Aquaculture, capture fisheries, and wild fish stocks. Resource and Energy Economics, 32: 65–77.

Kabir, M., and Ridler, N. B. 1984. The demand for Atlantic Salmon in Canada. Canadian Journal of Agricultural Economics, 32: 560–568.

Lam, V. W. Y., Sumaila, U. R., Dyck, A., Pauly, D., and Watson, R. 2011. Construction and first applications of a global cost of fishing database. ICES Journal of Marine Science, 68: 1996–2004.

Lütkepohl, H. 2005. New Introduction to Multiple Time Series Analysis. Springer, Berlin.

Merritt, J. H. 1982. Freezing and transport at sea and on shore. International Journal of Refrigeration, 5: 35–39.

Nielsen, M. 2009. Modelling fish trade liliberalisation: does fish trade liberalisation result in welfare gains or losses? Marine Policy, 33: 1–7.

Nielsen, M., Jensen, F., Setala, J., and Virtanen, J. 2009. Causality in demand: a co-integrated demand system for trout in Germany. Applied Economics, 43: 797–809.

Pantula, S. G., Gonzalez-Farias, G., and Fuller, W. A. 1994. A comparison of unit-root test criteria. Journal of Business and Economics Statistics, 12: 449–459.

Parente, J., Fonseca, P., Henriques, V., and Campos, A. 2008. Strategies for improving fuel efficiency in the Portuguese trawl fishery. Fisheries Research, 93: 117–124.

Peavey, S., Work, T., and Riley, J. 1994. Consumer attitudes toward fresh and frozen fish. Journal of Aquatic Food Product Technology, 3: 71–87.

Pedregal, D. J., and Trapero, J. R. 2012. The power of ECOTOOL Matlab Toolbox. *In* Industrial Engineering: Innovative Networks, chapter 36, pp. 319–328. Ed. by S. P. Sethi, M. Bogataj, and L. Ros-McDonnell. Springer, Cartagena, Spain.

Sinclair, M., Arnason, R., Csirke, J., Karnicki, Z., Sigurjonsson, J., Skjoldal, H. R., and Valdimarsson, G. 2002. Responsible fisheries in the marine ecosystem. Fisheries Research, 58: 255–265.

Stock, J. H., and Watson, M. W. 2010. Introduction to Econometrics, 3rd edn. Addison-Wesley, Amsterdam.

Suárez de Vivero, J., Frieyro de Lara, M., and Jurado Estévez, J. 1997. Decentralization, regionalization and co-management. A critical view on the viability of the alternative management models for fisheries in Spain. Marine Policy, 21: 197–206.

Sumaila, U. R., Teh, L., Watson, R., Tyedmers, P., and Pauly, D. 2008. Fuel price increase, subsidies, overcapacity, and resource sustainability. ICES Journal of Marine Science, 65: 832–840.

Surís-Regueiro, J. C., Varela-Lafuente, M. M., and Iglesias-Malvido, C. 2003. Effectiveness of the structural fisheries policy in the EU. Marine Policy, 27: 535–545.

Suuronen, P., Chopin, F., Glass, C., Løkkeborg, S., Matsushita, Y., Queirolo, D., and Rihan, D. 2012. Low impact and fuel efficient fishing—looking beyond the horizon. Fisheries Research, 119–120: 135–146.

Symes, D., and Phillipson, J. 2009. Whatever became of social objectives in fisheries policy? Fisheries Research, 95: 1–5.

Trondsen, T. 1997. Marketing potential and barriers for fresh packed fish. Journal of Food Products Marketing, 4: 79–99.

Vanhaecke, L., Verbeke, W., and De Brabander, H. F. 2010. Glazing of frozen fish: analytical and economic challenges. Analytica Chimica Acta, 672: 40–44.

Vanhonacker, F., Pieniak, Z., and Verbeke, W. 2010. Fish market segmentation based on consumers' motives, barriers and risk perception in Belgium. Journal of Food Products Marketing, 16: 166–183.

Westlund, L. 2005. Future prospects for fish and fishery products. Forecasting fish consumption and demand analysis: a literature review. FAO Fisheries Circular No. 972/5.

Wigren, R., and Wilhelmsson, M. 2007. Construction investments and economic growth in Western Europe. Journal of Policy Modeling, 29: 439–451.

Handling editor: Mitsutaku Makino