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Retail Fish Demand in Great Britain and its Fisheries Management Implications

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Abstract *Over the past 20 years, the demand for fish in the UK has changed markedly. The species prevalent in the consumption mix has altered to reflect the greater availability of farmed species and the decline in some marine-caught species. This paper examines the retail demand for fish in the UK and the implications this has for fisheries policy. A two-stage demand model using a dynamic Almost Ideal Demand System (AIDS) is estimated from retail panel data for fish and fish products in Great Britain.*[1] *Both conditional and unconditional expenditure, own- and cross-price elasticities of demand are derived from the parameter estimates. Haddock, salmon, flatfish, shellfish, and smoked fish are expenditure elastic, implying that income growth will strongly increase demand for these species. Most species are own-price inelastic, suggesting that policy-driven catch restrictions can increase expenditure on fish and may reduce the short-run incentives of commercial fishermen to comply.*

Key words Fish demand, UK, unconditional elasticities.

JEL Classification Codes D12, Q21, Q22, C51.

Introduction

During the last 25 years, there have been notable changes in the demand for fish in the UK. Household consumption of fish and fish products was 13% higher in 1999 than in 1979, while the share of expenditure on fish in total food spending rose from 4.3 to 5.5%. Over this period, the per capita consumption of fresh fatty fish or oily fish species, such as salmon, has more than doubled that of processed, canned and shellfish has increased by 60%, while that of fresh white and cooked fish (as in "fish and chips") declined (MAFF 2000). During this time, the EU conservation, trade, and market policies have exerted an increasing influence on the fishing industry. It is not surprising, therefore, that the empirical analysis of demand for fish in the UK has attracted the interest of a number of researchers in recent years.

In earlier studies, Ioannidis and Whitmarsh (1987) investigated the price forma-

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[1] Great Britain (GB) is comprised of the countries of England, Wales, and Scotland, but excludes Northern Ireland. The latter, with the three former countries constitute the whole of the United Kingdom. The data source for the empirical modelling relates to GB. Hence the distinction has been drawn between the two entities, GB and the UK, even though GB contains 97% of the UK population.

tion of fish at the wholesale level with emphasis on cod and haddock. Burton and Young (1992) examined the interactions between aggregate fish demand and demand for four meat species. Burton (1992) used both inverse and direct structural equation systems to obtain price flexibility and demand elasticity estimates for four broadly defined categories of wet fish (white, white smoked, fatty fish, and other). He subsequently tested the consistency of the UK fish consumption data with the Generalized Axiom of Revealed Preference (Burton 1994). Jaffry, Pascoe, and Robinson (1999) derived long-run price flexibilities for high-valued species (bass, lobster, sole, and turbot) using cointegration techniques; and Lechene (1999) considered the demand for fresh, processed, prepared, and frozen fish in the context of a structural system involving both meat species and fish.

A common problem in applied demand analysis is that while the number of commodities amongst which the consumer makes choices is potentially immense, the number of observations available to a researcher is typically very limited. This is especially true for time series observations. To overcome this problem, demand analysts explicitly (or implicitly) rely on the assumptions of weak separability and multi-stage budgeting. The former implies that commodities can be partitioned into a number of separate groups, where a change in the price of a commodity in one group affects the demand for all commodities in another group in exactly the same manner. The multi-stage budgeting implies that aggregate expenditure is first allocated among groups and subsequently (and independently) within each group. Thus, the weak separability allows a researcher to concentrate on a single group and estimate elasticities for the group members that are conditional on expenditures at earlier stages in the budget allocation process (Rickertsen 1998).

The assumptions of weak separability and multi-stage budgeting have also been employed in earlier works on demand for fish in the UK. Several focused on a very small number (up to four) of species. Examples are the works of Ioannidis and Whitmarsh (1987), Ioannidis and Matthews (1995) and Jaffrey, Pascoe, and Robinson (1999). Others considered highly aggregated commodities (*e.g*. Burton 1994; Burton and Young 1992; Lechene 1999). Drawing policy implications from the conditional elasticities, however, may turn out to be misleading since these typically differ from the unconditional ones (obtained from a model with a large number of goods). At the same time, working with broadly defined commodities may obscure valuable information on the interactions among individual fish species and products belonging to different aggregates.

Based on the assumptions of weak separability and multi-stage budgeting, Edgerton (1992) derived expressions for the calculation of unconditional expenditure and price elasticities from conditional ones. His work greatly alleviates the degrees-of-freedom problem and makes it possible to study the interrelationships among a large number of individual commodities. Empirical applications of his approach include Edgerton (1997), Rickertsen (1998), and Klonaris and Hallam (2003). In another paper, however, Carpentier and Guyomard (2001) showed that Edgerton's formulae fail to satisfy the symmetry requirement and developed alternative expressions which are consistent with the theoretical postulates. Their empirical illustration of dairy demand in France revealed that in a number of cases, considerable divergences existed between the unconditional elasticity estimates obtained under the two approaches.

The objective of this paper is to present an empirical analysis of the retail level demand for fish in GB. This is conducted using longitudinal consumer survey panel data on prices, quantities purchased, and total expenditures on 14 fish species and fish products and following the approach proposed by Carpentier and Guyomard (2001). The next section contains the analytical framework, followed by a section discussing the data and the empirical model. Next, the empirical results are presented. The demand elasticity estimates derived for the major species are used in the final section to draw policy implications regarding the incentives of individual fishermen to comply with policy-driven catch restrictions.

Analytical Framework

With n elementary commodities in the budget, the Marshallian unconditional demand function for commodity $i = 1, 2, \ldots, n$ may be written as:

$$q_i = f_i(p, y), \tag{1}$$

where p is a nx1 price vector and y is total expenditure. We denote the unconditional expenditure elasticity of i as E_i and the unconditional Marshallian and unconditional Hicksian elasticities with respect to $\rho_j (j = 1,2,\ldots,n)$ as E_{ij} and $\tilde{E}_{ij}$, respectively. Under the assumptions of weak separability and two-stage budgeting, the set of elementary commodities may be partitioned into N mutually exclusive and exhaustive groups $g = 1, 2, \ldots, G, \ldots, N$. The first-stage Marshallian demand function for group G may be written as:

$$q_G = h_G(P_1, \ldots, P_G, \ldots, P_N, y), \tag{2}$$

where q_G is real expenditure on all commodities in the group, and P's are the respective true cost of living (TCL) indices. We denote the expenditure elasticity for group G as E_G and the Marshallian and Hicksian elasticities with respect to the TCL index of group H as E_{GH} and $\tilde{E}_{GH}$, respectively. The expenditure on group G is further allocated in a second stage among its members. The conditional (within-group) Marshallian demand function of i may be written as:

$$q_i = h_i(p^G, y^G), \tag{3}$$

where p^G is the price vector of the elementary commodities belonging to group G, and y^G is the expenditure allocated to that group by the first-stage decisions. We denote the conditional expenditure elasticity of i as $E_{(G)i}$ and the conditional Marshallian and Hicksian elasticities with respect to p_j as $E_{(G)ij}$ and $\tilde{E}_{(G)ij}$, respectively.

Carpentier and Guyomard (2001) show that when the TCL indices do not vary much with the utility levels (or equivalently when the TCL indexes are highly collinear with the Paasche or the Laspeyeres indices), the unconditional elasticities can be calculated as:

$$E_i = E_{(G)i} E_G \tag{4a}$$

$$\tilde{E}_{ij} = \tilde{E}_{(G)ij} + w_{(H)j} \tilde{E}_{GH} E_{(G)i} E_{(H)j} \tag{4b}$$

$$E_{ij} = E_{(G)ij} + w_{(H)j} \left(\frac{\delta_{GH}}{E_{(H)j}} + E_{GH} \right) E_{(G)i} E_{(H)j} + w_{(H)j} w_H E_G E_{(G)i} (E_{(H)i} - 1), \tag{4c}$$

where δ_{GH} is the Kronecker delta ($\delta_{GH} = 1$, for $G = H$ and zero otherwise); w_H is the share of group H in total expenditure and $w_{(H)j}$ for the share of commodity j in group H; $E_{(G)ij}$ and $\tilde{E}_{(G)ij}$ are both zero for $G \neq H$ (that is when i and j belong to different groups).

Data and the Empirical Model

The empirical investigation here utilizes calendar monthly data on prices, retail purchases and expenditure for 14 fish species and fish products over the period February 1992 to November 2001. These were derived from the AGB Taylor Nelson Sofres (TNS) consumer Superpanel data which covers GB and comprises a continuous sample of between 8,000–10,000 households over the sample period.[2] For this analysis, the elementary commodities must be grouped or classified in some way. We have adopted the classification of TNS, and for the first-stage allocation we consider four broadly defined aggregate fish commodities: fresh natural, fresh processed, frozen, and shellfish. Therefore, the first-stage budgeting involves a four-commodity demand system. This particular grouping is similar to the one adopted by Manrique and Jensen (2001) in their study of demand for fish in Spain.[3]

In the second stage, expenditure on fresh natural fish is then allocated among cod, haddock, flatfish (plaice and sole), fatty fish (herring and mackerel), salmon, and trout. Expenditure on fresh processed is further allocated among cakes/fingers, smoked raw fish to be cooked, and smoked to eat cold, and expenditure on frozen fish is allocated among frozen natural, frozen processed, frozen semi-processed/prepared meals, and other frozen. Therefore, the second-stage budgeting involves three demand systems with six, three, and four equations, respectively. Figure 1 presents the utility tree for the empirical analysis, while table 1 gives the basic descriptive statistics on prices, retail purchases, and expenditure shares for the 14 fish species and fish products. The TCL indices required for the first-stage analysis were approximated by Paasche price indices, given as

$$P_P^t = \frac{\sum_{i=1}^{n} p_i^t q_i^t}{\sum_{i=1}^{n} p_i^0 q_i^t},$$

where t is the current period and 0 is the base period.

The demand for fish in GB is modelled here using the nonlinear Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980). In the AIDS model, the

[2] The data were supplied by the Sea Fish Industry Authority, Edinburgh, Scotland, UK. TNS collect household panel data for Great Britain to provide longitudinal (time series) estimates of four-weekly aggregate household expenditure and volumes in terms of tonnes of product weight. The four-weekly data were subsequently converted in this study into a calendar monthly basis.

[3] The estimation of the first-stage system implies that the four broadly defined fish commodities are weakly separable from other foods. This may be questionable since other foods include meat which may interact with fish. Relevant empirical evidence, however, supports our approach. Specifically, both Garcia and Albisu (1995) and Salvanes and DeVoretz (1997) found that although aggregate fish cannot be modeled separately from aggregate meat, disaggregated meats are weakly separable from different product forms of fish. Also, in the work of Burton and Young (1992) none of the cross-price elasticities (Hicksian or Marshallian) of aggregate fish with respect to the four meats were found to be statistically significant at any reasonable level.

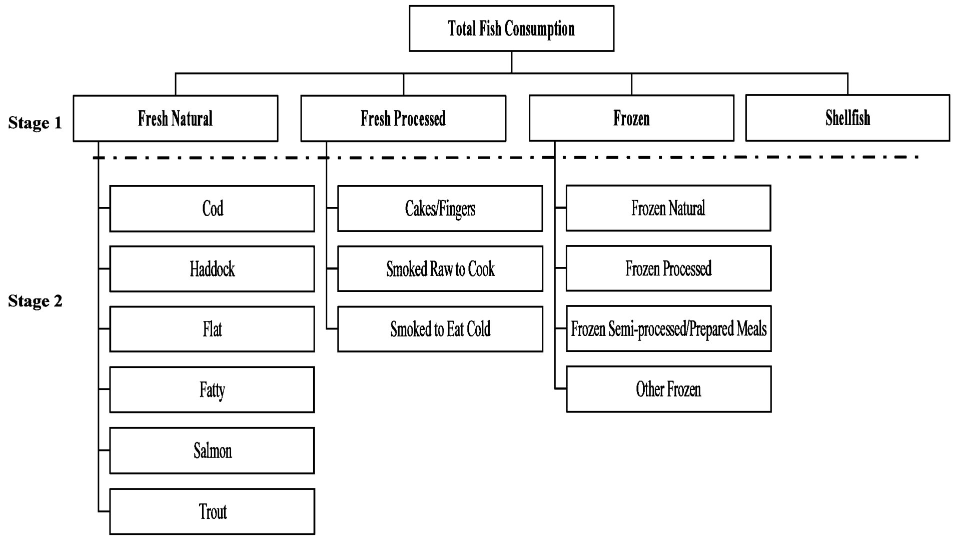

Figure 1. Utility Tree

Table 1
Descriptive Statistics of Prices, Purchases, and Expenditure Shares

	Price		Purchases		Share	
Commodity*	Average	St. Dev.	Average	St. Dev.	Average	St. Dev.
Cod	5.883	1.760	47.10	299.75	0.077	0.011
Haddock	6.034	1.331	1,273.34	260.68	0.077	0.0
Flat	7.030	1.680	581.21	153.87	0.041	0.009
Fatty fish	3.125	1.334	365.35	116.69	0.011	0.003
Salmon	8.746	6.575	1,003.29	368.69	0.069	0.024
Trout	4.890	0.982	406.21	59.22	0.020	0.003
Cakes/fingers	6.928	5.441	176.76	76.19	0.010	0.004
Smoked raw to cook	4.938	1.399	1,012.34	234.31	0.049	0.008
Smoked to eat cold	8.823	4.969	503.67	175.59	0.041	0.016
Frozen natural	4.720	0.518	879.29	157.34	0.042	0.004
Frozen processed	3.904	0.336	6,916.03	774.58	0.276	0.021
Frozen semi-processed/ prepared meals	4.015	0.238	3,089.36	397.48	0.127	0.015
Other frozen	7.307	0.599	86.55	443.64	0.104	0.034
Shellfish	1.317	0.423	779.74	155.50	0.055	0.011

* Prices are expressed in £/kg and purchases in tonnes per month.

expenditure share of commodity i, w_i, is given by:

$$w_i = a_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln(y/P), \tag{5}$$

where $\ln P$ is a price index defined as:

$$\ln P = a_0 + \sum_{l=1}^{n} a_l \ln p_l + 0.5 \sum_{l=1}^{n} \sum_{j=1}^{n} \gamma_{lj} \ln p_l \ln p_j . \tag{6}$$

Economic theory stipulates the following restrictions on the model parameters:

(additivity) (7a)

(homogeneity) (7b)

(symmetry). (7c)

The expenditure elasticity for i is given by:

(8a)

the Marshallian price elasticity is given by:

(8b)

and the Hicksian price elasticity is given by:

(8c)

The Kronecker delta (δ) takes value 1 for $i = j$ and zero, otherwise.

Earlier empirical studies have shown that the static AIDS in equation (5) may perform poorly with time series data, and the problem may be addressed by allowing for dynamic (habit-persistence or partial adjustment) effects. To this end, a number of approaches has been proposed in the literature, prominent among which are the general dynamic framework (*e.g.*, Anderson and Blundell 1983; Burton and Young 1992), the inclusion of a vector of lagged consumptions (*e.g.*, Chen and Veeman 1991), and the inclusion of a vector of lagged expenditure shares (*e.g.*, Alessie and Kapteyn 1991). Here, the latter approach has been adopted because it is simple to implement and at the same time preserves additivity. Guided by the fact that the data are calendar monthly, a twelve-month lag in each of the commodity shares from each system has been included on the right-hand side to account for dynamic effects. In addition, 11 monthly dummies have been added to capture potential seasonal influences. With the latter two modifications, equation (5) for any time t may be rewritten as:

(9)

where D_m stands for the *m*th monthly dummy. Because of the inclusion of dynamic effects, the theoretical restriction $\Sigma_i a_i = 1$ in equation (7a) has been replaced by $\Sigma_i a_{i0} = 1$ and $\Sigma_i \rho_{ij} = 0 \ \forall \ j$, while $\Sigma_j \rho_{ij} = 0 \ \forall \ i$ is imposed for system identification (Rickertsen 1998).

Empirical Results

The four systems with the theoretical conditions of symmetry and homogeneity imposed *a priori* have been estimated using the iterated non-linear Seemingly Unrelated Regressions Equations procedure (LSQ) in the TSP 4.5 program. Given that the budget shares sum to one, the error covariance matrix of the residuals is singular and one equation has been dropped for estimation. The coefficients of the omitted equation in each system have been recovered from the theoretical restrictions (symmetry, homogeneity, and additivity). In the interest of space, full estimation results are not reported here. They are, however, available from the authors upon request. The estimated models appear to fit the data reasonably well. The system coefficient of determination for the broadly defined fish commodities is 0.678, for fresh natural is 0.601, for fresh processed is 0.749, and for frozen is 0.547.[4] Consumer behaviour is consistent with utility maximization when the matrix of Hicksian effects is negative definite. The eigenvalues of the four Hicksian matrices calculated at the sample means are all negative, implying that the empirical results are consistent with the utility maximization hypothesis.[5]

Table 2 presents elasticity estimates for the system of the broadly defined fish commodities.[6] All own-price Hicksian elasticities are statistically significant and substantially lower than one (in absolute values). All cross-price elasticities are positive, suggesting that the broad fish commodities are *net* substitutes in consumption, something which complies perfectly with *a priori* expectations. Moreover, all but one pair (fresh processed-shellfish) is statistically significant. The Marshallian elasticities for frozen and fresh natural fish are substantially higher than the corresponding Hicksian ones, indicating strong real expenditure effects. Statistically significant *gross* complementarities appear to be present for the pairs fresh natural-frozen, frozen-fresh processed, and shellfish-frozen. The expenditure elasticities are very close to one with shellfish having the highest (1.05) and frozen the lowest (0.95).

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[4] For consistent systems, single-equation R^2 statistics have no obvious interpretation. In this paper, we use the system coefficient of determination proposed by Bewley (1983), which is calculated as:

$$R_s^2 = 1 - \frac{1}{1 + \dfrac{LR}{T(n-1)} \dfrac{T-k}{T}},$$

where LR is twice the difference between the log-likelihood function of the estimated model and the likelihood function of the "base" model (includes only the intercepts on the right-hand side), T is the number of observations, n is the number of equations, and k is the average number of parameters per equation. The ratio $(T - k)/T$ serves as a small sample adjustment factor (Burton and Young 1992).

[5] The eigenvalue vectors are (-0.12, -0.1, -0.04, $-0.5\text{x}10^{-5}$), (-0.19, -0.14, -0.07, -0.05, -0.01, $-0.1\text{x}10^{-3}$), (-0.37, -0.14, -0.02), and (-0.40, -0.12, -0.05, $-0.5\text{x}10^{-5}$).

[6] All elasticities have been calculated at sample means.

Table 2
Elasticities for the Broadly Defined Fish Commodities

	Hicksian				Marshallian				Expenditure
Commodity	1	2	3	4	1	2	3	4	
Fresh Natural	–0.32*	0.10*	0.14*	0.07*	–0.62*	0.001	–0.42*	0.02	1.02*
	(0.05)[1]	(0.02)	(0.05)	(0.03)	(0.05)	(0.02)	(0.05)	(0.03)	(0.03)
Fresh Processed	0.30*	–0.62*	0.30*	0.03	0.02	–0.72*	–0.23*	–0.03	0.95*
	(0.06)	(0.05)	(0.07)	(0.03)	(0.05)	(0.05)	(0.06)	(0.03)	(0.04)
Frozen	0.08*	0.05*	–0.16*	0.03	–0.22*	–0.05*	–0.70*	–0.03*	0.99*
	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)	(0.01)
Shellfish	0.38*	0.05	0.26*	–0.69*	0.08	–0.06	–0.32*	–0.77*	1.05*
	(0.14)	(0.06)	(0.10)	(0.17)	(0.11)	(0.05)	(0.11)	(0.27)	(0.17)

Notes: [1] Standard errors in parentheses; *statistically significant at the 5% level or less.

Table 3a presents conditional elasticity estimates for the fresh natural fish subcategory. The own-price compensated elasticities are all statistically significant and lower than one (in absolute values). The majority of Hicksian cross-price elasticities are positive and statistically significant. Exceptions are the interactions of trout with haddock, flatfish, and salmon. This result, however, does not necessarily imply the presence of *net* complementarities since none of those interactions is statistically significant. When the income effects of price changes are taken into account through the Marshallian elasticities, the overwhelming majority of fresh natural fish turn out to be *gross* complements (a relationship which in most cases is statistically significant). The demand for salmon and haddock appear to be real-expenditure elastic, while that for trout is quite inelastic. Table 3b presents conditional elasticity estimates for fresh processed. Again, the compensated own-price responses are inelastic. All cross-price elasticities are positive, suggesting that fresh processed fish are all *net* substitutes. The uncompensated own-price elasticity of smoked to eat cold is higher than one (in absolute value). Statistically significant *gross* complementarities appear to exist for the pairs cakes/fingers—smoked to eat cold and cakes/fingers—smoked raw to cook. Table 3c presents conditional elasticity estimates for frozen fish. The own-price Hicksian elasticity for other frozen is well above one (in absolute value), while those for frozen processed and semi-processed are below 0.4 (in absolute values). All pairs but frozen natural—frozen processed appear as *net* substitutes. The Hicksian interaction between frozen natural and frozen processed, however, is not statistically significant. Statistically significant *gross* substitutability appears to be present for the pairs natural-semi-processed and processed-other frozen; statistically significant *gross* complementarity appears to be present for the pair processed-semi-processed. The expenditure elasticity of other frozen is quite high (1.92), while those for the rest are below unity.

Burton (1992) reported Hicksian own-price elasticities ranging from –0.06 for other wet to –1.55 for fatty fish, Marshallian own-price elasticities ranging from –0.4 for other wet to –1.6 for fatty fish, and real expenditure elasticities ranging from 0.49 for fatty fish to 1.90 for other wet. Burton and Young (1992) using quarterly data (1961:1 to 1986:4) found a Hicksian own-price elasticity for aggregate fish of –0.08, a Marshallian own-price elasticity of –0.66, and a unitary real expenditure elasticity. Lechene (1999) using monthly data (1988:1 to 1999:12) obtained Hicksian own-price elasticities ranging from –0.03 for prepared fish to –0.75 for

Table 3a
Conditional Elasticities for Fresh Natural Fish

	Hicksian						Marshallian						Expenditure
Commodity	1	2	3	4	5	6	1	2	3	4	5	6	
Cod	–0.54*	0.22*	0.10*	0.02*	0.15*	0.05	–0.80*	–0.03	–0.04	–0.01	–0.08*	–0.01	0.98*
	(0.03)	(0.04)	(0.03)	(0.01)	(0.02)	(0.03)	(0.03)	(0.04)	(0.03)	(0.01)	(0.02)	(0.03)	(0.03)
Haddock	0.22*	–0.40*	0.04	0.01	0.16*	–0.03	–0.07	–0.69*	–0.11*	–0.03	–0.10*	–0.10*	1.10*
	(0.04)	(0.07)	(0.04)	(0.02)	(0.03)	(0.04)	(0.04)	(0.07)	(0.05)	(0.02)	(0.03)	(0.04)	(0.04)
Flat	0.18*	0.08	–0.39*	0.02	0.16*	–0.04	–0.08	–0.19*	–0.53*	–0.02	–0.07*	–0.11	1.00*
	(0.05)	(0.08)	(0.08)	(0.02)	(0.04)	(0.05)	(0.05)	(0.08)	(0.08)	(0.02)	(0.03)	(0.06)	(0.07)
Fatty fish	0.16*	0.05	0.06	–0.44*	–0.08	0.86*	–0.05	–0.15	–0.04	–0.47*	–0.26*	0.19*	0.78*
	(0.07)	(0.11)	(0.07)	(0.05)	(0.06)	(0.09)	(0.07)	(0.10)	(0.08)	(0.05)	(0.06)	(0.09)	(0.08)
Salmon	0.17*	0.18*	0.10*	–0.01	–0.40*	–0.03	–0.11*	–0.10*	–0.05*	–0.05*	–0.65*	–0.11*	1.07*
	(0.02)	(0.03)	(0.02)	(0.01)	(0.03)	(0.04)	(0.03)	(0.03)	(0.02)	(0.01)	(0.03)	(0.04)	(0.04)
Trout	0.21*	–0.11	–0.10	0.13*	–0.11	–0.75*	0.06	–0.25	–0.16	0.11*	–0.24*	–0.79*	0.56*
	(0.11)	(0.14)	(0.11)	(0.05)	(0.13)	(0.37)	(0.10)	(0.13)	(0.11)	(0.05)	(0.11)	(0.38)	(0.17)

Notes: Standard errors in parentheses; *statistically significant at the 5% level or less.

Table 3b
Conditional Elasticities for Fresh Processed

	Hicksian			Marshallian			Expenditure
Commodity	1	2	3	1	2	3	
Cakes/Fingers	–0.80*	0.18	0.62*	–0.87*	–0.15	0.36	0.66*
	(0.15)	(0.14)	(0.25)	(0.13)	(0.12)	(0.30)	(0.17)
Smoked raw to cook	0.04	–0.30*	0.27*	–0.06*	–0.79*	–0.12	0.97*
	(0.03)	(0.04)	(0.06)	(0.02)	(0.01)	(0.09)	(0.07)
Smoked to eat cold	0.15*	0.34*	–0.71*	0.04	–0.23*	–1.16*	1.12*
	(0.06)	(0.08)	(0.13)	(0.05)	(0.04)	(0.09)	(0.09)

Notes: Standard errors in parentheses; *statistically significant at the 5% level or less.

Table 3c
Conditional Elasticities for Frozen Fish

	Hicksian				Marshallian				Expenditure
Commodity	1	2	3	4	1	2	3	4	
Frozen natural	–0.93*	0.14	0.59*	0.20	–0.99*	–0.25	0.41*	0.06	0.77*
	(0.16)	(0.17)	(0.13)	(0.15)	(0.16)	(0.20)	(0.13)	(0.17)	(0.19)
Frozen processed	0.02	–0.37*	–0.02	0.37*	–0.03	–0.73*	–0.18*	0.24*	0.71*
	(0.03)	(0.06)	(0.03)	(0.06)	(0.03)	(0.07)	(0.04)	(0.07)	(0.10)
Frozen semi-processed	0.20*	–0.04	–0.32*	0.16	0.12*	–0.53*	–0.54*	–0.02	0.97*
	(0.04)	(0.07)	(0.10)	(0.10)	(0.04)	(0.10)	(0.10)	(0.12)	(0.13)
Other frozen	0.08	0.99*	0.20	–1.27*	–0.07	0.03	–0.25*	–1.63*	1.92*
	(0.06)	(0.16)	(0.13)	(0.22)	(0.06)	(0.19)	(0.13)	(0.25)	(0.30)

Notes: Standard errors in parentheses; *statistically significant at the 5% level or less.

fresh fish and real expenditure elasticities ranging from 0.1 for frozen to 0.5 for processed and shellfish. Comparisons of such elasticity estimates from different studies are often useful for detecting changes in consumer behaviour over time or even drawing policy implications. They are, however, relevant only when the studies involve the same commodities. This is clearly not the situation in comparing the present study with the earlier works on retail demand for fish in the UK, which involve fish species and products at very different levels of aggregation. Bearing this limitation in mind, one may observe that with regard to the Hicksian own-price elasticities, our results are qualitatively similar to those by Lechene (1999) and Burton and Young (1992), in the sense that all these studies imply inelastic compensated own-price responses. They are also qualitatively similar to results of Burton and Young (1992) with regard to real expenditure effects, in the sense that in both studies the expenditure elasticities are found to be close to unity.

Table 4a presents the derived unconditional Hicksian elasticities. The own-price elasticities are, as expected, higher (in absolute value terms) than the corresponding conditional ones. The differences range from a low of 0.01 (trout) to a high of 0.3

Table 4a
Unconditional Hicksian Elasticities

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	–0.62*	0.13*	0.05*	0.01	0.08*	0.04	0.007*	0.05*	0.04*	0.007	0.05*	0.03*	0.05*
	(0.03)	(0.04)	(0.025)	(0.01)	(0.02)	(0.03)	(0.002)	(0.01)	(0.01)	(0.004)	(0.02)	(0.01)	(0.01)
2	0.13*	–0.49*	–0.008	–0.002	0.07*	–0.04	0.007*	0.06*	0.05*	0.009*	0.05*	0.04*	0.06*
	(0.04)	(0.07)	(0.04)	(0.02)	(0.03)	(0.04)	(0.002)	(0.01)	(0.01)	(0.003)	(0.02)	(0.01)	(0.01)
3	0.10*	–0.02	–0.44*	0.008	0.08*	–0.05	0.007*	0.05*	0.04*	0.007	0.05*	0.03*	0.05*
	(0.05)	(0.08)	(0.08)	(0.02)	(0.04)	(0.05)	(0.002)	(0.01)	(0.01)	(0.004)	(0.02)	(0.01)	(0.01)
4	0.09	–0.02	0.03	–0.46*	–0.14*	0.23*	0.005*	0.04*	0.04*	0.007*	0.04*	0.03*	0.04*
	(0.07)	(0.10)	(0.08)	(0.05)	(0.06)	(0.08)	(0.002)	(0.01)	(0.01)	(0.003)	(0.02)	(0.01)	(0.01)
5	0.08*	0.08*	0.05*	–0.02*	–0.48*	–0.05	0.007*	0.05*	0.05*	0.01*	0.05*	0.03*	0.06*
	(0.02)	(0.03)	(0.02)	(0.01)	(0.03)	(0.03)	(0.002)	(0.01)	(0.01)	(0.004)	(0.02)	(0.01)	(0.01)
6	0.16	–0.16	–0.11	0.13*	–0.15	–0.76*	0.003	0.03*	0.03*	0.003	0.03*	0.02	0.03*
	(0.10)	(0.14)	(0.11)	(0.05)	(0.12)	(0.38)	(0.002)	(0.01)	(0.01)	(0.002)	(0.01)	(0.02)	(0.01)
7	0.05*	0.06*	0.03*	0.006*	0.005*	0.05	–0.83*	–0.02	0.44	0.01	0.07*	0.04*	0.07*
	(0.02)	(0.03)	(0.008)	(0.003)	(0.001)	(0.03)	(0.13)	(0.11)	(0.28)	(0.006)	(0.03)	(0.02)	(0.01)
8	0.08*	0.08*	0.04*	0.008*	0.07*	0.01*	–0.004	–0.60*	–0.003	0.02*	0.10*	0.06*	0.10*
	(0.02)	(0.01)	(0.008)	(0.002)	(0.002)	(0.003)	(0.02)	(0.01)	(0.06)	(0.01)	(0.03)	(0.02)	(0.02)
9	0.09*	0.1*	0.04*	0.01*	0.08*	0.01*	0.11	–0.004	–0.86*	0.02	0.12*	0.07*	0.12*
	(0.02)	(0.002)	(0.01)	(0.003)	(0.02)	(0.003)	(0.07)	(0.08)	(0.18)	(0.012)	(0.04)	(0.02)	(0.02)
10	0.02	0.02*	0.008	0.002*	0.02*	0.01	0.004	0.02*	0.02	–0.94*	0.09	0.57	0.15
	(0.015)	(0.006)	(0.005)	(0.001)	(0.01)	(0.006)	(0.003)	(0.01)	(0.013)	(0.16)	(0.17)	(0.13)	(0.15)
11	0.01*	0.02*	0.008*	0.002*	0.01*	0.002*	0.003*	0.02*	0.02*	0.01	–0.41*	–0.05	0.33*
	(0.004)	(0.008)	(0.003)	(0.001)	(0.005)	(0.0006)	(0.001)	(0.006)	(0.006)	(0.03)	(0.06)	(0.03)	(0.06)
12	0.02*	0.02*	0.01*	0.002*	0.02*	0.003	0.003*	0.03*	0.02*	0.19*	–0.97*	–0.35*	0.11
	(0.007)	(0.005)	(0.003)	(0.001)	(0.007)	(0.002)	(0.001)	(0.01)	(0.006)	(0.04)	(0.07)	(0.10)	(0.10)
13	0.04*	0.04*	0.02*	0.004*	0.04*	0.006*	0.007*	0.05*	0.05*	0.06	0.89*	0.13	–1.38*
	(0.008)	(0.007)	(0.004)	(0.001)	(0.007)	(0.002)	(0.001)	(0.007)	(0.008)	(0.06)	(0.17)	(0.12)	(0.23)

Notes: Standard errors in parentheses, computed as suggested in Kmenta (1986), pp 485–7; * statistically significant at the 5% level (or less).
(1) Cod, (2) Haddock, (3) Flat, (4) Fatty fish, (5) Salmon, (6) Trout, (7) Cakes/Fingers, (8) Smoked Raw to Cook, (9) Smoked to Eat Cold, (10) Frozen Natural, (11) Frozen Processed, (12) Frozen Semi–processed, (13) Other Frozen.

(smoked raw to cook). The within-group, cross-price elasticities are considerably different from the corresponding conditional ones. With very few exceptions (concerning largely the interactions between frozen natural and certain members of the fresh natural and the fresh processed groups), the cross-price elasticities between commodities in different groups are statistically significant, suggesting that the interactions between fish species and products in different groups are certainly relevant for market and policy analysis. In the overwhelming majority of cases, the cross-price elasticities are positive indicating *net* substitutability. The only notable exception is that between salmon and fatty fish, where the negative sign indicates *net* complementarity and the interaction between the two commodities is statistically significant (although marginally) at the 5% level. As a rule, the within-group, cross-price elasticities tend to be considerably larger than those concerning fish species and fish products in different groups.

Table 4b presents the unconditional real expenditure and Marshallian elasticities. The real expenditure elasticities are similar to the conditional ones. This is because the real expenditure elasticities for the broadly defined commodities are all close to unity. The own-price Marshallian elasticities, however, are considerably different than the corresponding conditional ones. For instance, the unconditional Marshallian for smoked raw to cook is two times its conditional, and that of smoked to eat cold is –1.04 while its conditional is –0.71. The uncompensated interactions between the members of fresh natural and the members of fresh processed are, in general, not statistically significant. However, those between the members of fresh natural and the members of frozen, as well as those between the members of frozen and the members of fresh processed are, in the majority of cases, statistically significant and have negative signs indicating *gross* complementarities.

Conclusions and Policy Implications

Market and policy analysis requires reliable and detailed information on interactions among commodities in the budget. Concentrating on a small number of products and computing conditional elasticities may turn out to be misleading, since these often differ from the unconditional ones. Alternatively, working with broadly defined groups of products disregards potentially valuable information on the interactions among their constituent elements belonging to different aggregates.

The empirical analysis of the retail level fish demand in GB here relies on a two-stage budgeting process which allows a large number of fish species and products to be considered individually, and a theoretically consistent approach for the calculation of their unconditional elasticities. According to the results, the within-group conditional Hicksian and Marshallian price elasticities are in many cases substantially different in magnitude from the policy relevant unconditional ones. Also, a large number of statistically significant interactions appears to exist among the individual fish and fish products belonging to different aggregates (fresh natural, fresh processed, and frozen). The results, therefore, appear to justify the approach adopted in this paper.

The real expenditure elasticities for haddock, salmon, flatfish, shellfish, smoked to eat cold, and other frozen fish are all greater than unity. This suggests that increases in consumer expenditure for fish, in general, are likely to increase the demand for those commodities relative to fish species and products which appear to be quite real expenditure inelastic, such as trout, frozen semi-processed, and smoked raw to cook fish. Except for other frozen fish (a category containing exotic high-value species), all unconditional Hicksian own-price elasticities are lower than unity (in absolute value). Furthermore, with the exception of smoked fish to eat cold (*e.g.*,

Table 4b
Unconditional Marshallian and Expenditure Elasticities

	Marshallian													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Expend
1	–0.70*	0.06	0.01	0.002	0.005	0.02	–0.003	–0.001	0.005	–0.04*	–0.23*	–0.1*	–0.05*	1.00*
	(0.03)	(0.04)	(0.03)	(0.01)	(0.02)	(0.03)	(0.002)	(0.01)	(0.01)	(0.004)	(0.02)	(0.01)	(0.02)	(0.04)
2	0.05	–0.59*	–0.05	–0.015	–0.005	–0.06	–0.004	–0.002	0.006	–0.04*	–0.25*	–0.11*	–0.06*	1.12*
	(0.04)	(0.07)	(0.04)	(0.01)	(0.03)	(0.04)	(0.003)	(0.01)	(0.01)	(0.005)	(0.02)	(0.01)	(0.02)	(0.04)
3	0.02	–0.09	–0.48*	–0.003	0.01	–0.07	–0.004	–0.001	0.005	–0.04*	–0.23*	–0.1*	–0.05*	1.03*
	(0.05)	(0.08)	(0.08)	(0.02)	(0.03)	(0.05)	(0.003)	(0.01)	(0.01)	(0.005)	(0.02)	(0.03)	(0.02)	(0.07)
4	0.03	–0.08	–0.001	–0.46*	–0.20*	0.22*	–0.003	–0.001	0.004	–0.03*	–0.18*	–0.08*	–0.04	0.80*
	(0.07)	(0.11)	(0.07)	(0.05)	(0.06)	(0.09)	(0.002)	(0.008)	(0.008)	(0.004)	(0.02)	(0.01)	(0.03)	(0.08)
5	–0.001	–0.004	0.003	–0.03*	–0.56*	–0.07*	–0.004	–0.001	0.006	–0.04*	–0.25*	–0.11*	0.06*	1.10**
	(0.02)	(0.03)	(0.02)	(0.01)	(0.03)	(0.03)	(0.003)	(0.01)	(0.01)	(0.005)	(0.02)	(0.01)	(0.02)	(0.04)
6	0.12	–0.20	–0.13	0.12*	–0.19	–0.77*	–0.003	–0.001	0.003	–0.02*	–0.13*	–0.05*	–0.03	0.58*
	(0.10)	(0.13)	(0.10)	(0.05)	(0.11)	(0.37)	(0.002)	(0.006)	(0.006)	(0.007)	(0.04)	(0.02)	(0.03)	(0.17)
7	0.003	0.01	0.002	–0.001	0.007	–0.005	–0.72*	–0.33*	0.12	–0.02*	–0.10*	–0.04*	0.006	0.62*
	(0.008)	(0.01)	(0.005)	(0.001)	(0.008)	(0.03)	(0.06)	(0.06)	(0.20)	(0.006)	(0.03)	(0.01)	(0.02)	(0.16)
8	0.004	0.01	0.004	–0.002	0.01	–0.01*	0.39*	–0.64*	0.06*	–0.02*	–0.15*	–0.05*	0.008	0.92*
	(0.01)	(0.01)	(0.007)	(0.002)	(0.01)	(0.004)	(0.02)	(0.02)	(0.03)	(0.007)	(0.03)	(0.02)	(0.03)	(0.06)
9	0.005	0.02	0.004	–0.002	0.01	–0.008	0.44*	–0.12	–1.04*	–0.03*	–0.18*	–0.06*	0.01	1.07*
	(0.01)	(0.02)	(0.009)	(0.002)	(0.01)	(0.01)	(0.13)	(0.14)	(0.15)	(0.007)	(0.03)	(0.02)	(0.03)	(0.09)
10	–0.004	–0.04*	–0.02*	–0.006*	–0.04*	–0.01	–0.005*	–0.02*	–0.01	–0.96*	–0.12	0.47*	0.10	0.76*
	(0.01)	(0.01)	(0.006)	(0.002)	(0.01)	(0.008)	(0.002)	(0.007)	(0.006)	(0.16)	(0.18)	(0.13)	(0.16)	(0.19)
11	–0.04*	–0.04*	–0.02*	–0.006*	–0.03*	–0.01*	–0.005*	–0.02*	–0.01*	–0.01	–0.61*	–0.13*	0.27*	0.70*
	(0.006)	(0.006)	(0.003)	(0.001)	(0.006)	(0.002)	(0.001)	(0.005)	(0.005)	(0.03)	(0.07)	(0.03)	(0.07)	(0.10)
12	–0.06*	–0.05*	–0.03*	–0.01	–0.05*	–0.02*	–0.006*	–0.02*	–0.02	0.17*	–0.36*	–0.47*	0.21	0.96*
	(0.008)	(0.008)	(0.005)	(0.001)	(0.007)	(0.002)	(0.001)	(0.008)	(0.006)	(0.04)	(0.08)	(0.10)	(0.15)	(0.13)
13	–0.11*	–0.11*	–0.06	–0.02*	–0.09*	–0.03*	–0.01*	–0.05*	–0.03*	0.001	0.36*	–0.11	–1.18*	1.91*
	(0.02)	(0.02)	(0.01)	(0.002)	(0.02)	(0.005)	(0.003)	(0.01)	(0.01)	(0.07)	(0.16)	(0.12)	(0.22)	(0.29)

Notes: Standard errors in parentheses, computed as suggested in Kmenta (1986), pp 485–7; * statistically significant at the 5% level (or less).
(1) Cod, (2) Haddock, (3) Flat, (4) Fatty fish, (5) Salmon, (6) Trout, (7) Cakes/Fingers, (8) Smoked Raw to Cook, (9) Smoked to Eat Cold, (10) Frozen Natural, (11) Frozen Processed, (12) Frozen Semi-processed, (13) Other Frozen.

smoked salmon) and other frozen fish, all unconditional own-price Marshallian elasticities are lower than unity (in absolute value). We may conclude, therefore, that the demand for fish and fish products in GB is generally own-price inelastic, with the exception of certain luxury fish products. Among the least responsive commodities to own-price changes are haddock, flatfish, fatty fish, salmon, frozen processed, and frozen semi-processed fish, for which both the Hicksian and the Marshallian unconditional elasticities are below 0.6.

It is well known that, because of the duality between quantities and prices, demand elasticities are inversely related to price flexibilities (that is, a low demand elasticity suggests a high price flexibility and vice versa). The demersal (whitefish) species cod, haddock, and flatfish, which are subject to stock conservation policies, are quite price inelastic. Given the inverse relationship between flexibilities and elasticities, supply restrictions on cod, haddock, and flatfish are likely to lead to a more-than-proportionate rise in retail prices, thus increasing total consumer expenditure on these species. A relevant question is whether the increase in prices and sales revenue will provide an incentive or a disincentive for individual fishermen to comply with catch restrictions. Under an assumption that such retail price changes are transmitted into quayside and first-hand selling prices, the answer will depend on the fishermen's behaviour. To the extent that all fishermen obey the rules and act collectively, it would be in their interest to comply with quotas for both the revenue-increasing effect as well as for conservation. Conversely, if the individual fishermen are price takers they would always be reluctant to comply, no matter what the price flexibility is.

The experience of the operation of the quota system in the EU (and the UK) for more than 20 years suggests that fishermen are more likely to act as an individuals rather than in the common interest. A manifestation of such behaviour is the development of a "black market" for species which are subject to quotas. The limited compliance was officially recognized by the EU Commission and admitted by the UK's National Association of Fishermen (Karagiannakos 1995). Furthermore, an ongoing investigation by the Strategy Unit of the Prime Minister of the UK has been reported to have found "that British fishermen are breaking the law and landing far more fish than they are allowed. Since the numbers of days fishermen are allowed at sea have been cut, illegal landings have shot up by 200% in some parts of the country" (BBC 2004). High price flexibilities, when combined with supply restrictions, provide individual fishermen with even stronger incentives for noncompliance. It appears, therefore, that there is scope for stricter monitoring and surveillance of the activities of trawlers (which target mainly demersal species). In addition, there is a need for greater regulation and control within the producer organizations (of which there are some 21 such bodies in the UK), established in the context of the Common Fisheries Policy by Regulation 3759/92, which encourage cooperation, supply management, and fishing along rational lines.

We also observe that salmon, which in the past had a luxury image (as a wild capture species), but which is now largely supplied through aquaculture, belongs to the group of price inelastic fish products. This is an indication that the species is now regarded by consumers as a basic fish commodity and a net substitute for whitefish. This is in contrast to its smoked counterpart and frozen other fish (which includes many exotic species), both of which are price elastic and retain their luxury image. From the perspective of marine coastal management, any restrictions on further supply expansion of salmon or limitation on supplies, either through site withdrawal or lower stocking densities to meet welfare requirements, seem unlikely to result in lower industry revenues. Given that the demand for salmon is price flexible, any proportionate reduction in the quantity marketed will be outweighed by the corresponding increase in price.

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