# Demand interaction between farmed Salmon and wild caught fish in the United Kingdom

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## Abstract

Demand relationships between salmon and a number of wild-caught whitefish and shellfish species using both single equation models and linearised AIDS system framework. The system is well represented although autocorrelation were found in both approaches but this is less of a problem in the systems approach. A cautious interpretation of the results indicated that salmon had a long-run market relationship with the whitefish species of cod, monkfish, saithe, whiting and plaice and with the shellfish species of mussels, nephrops, scallops and shrimp. These groups contain the main seafood species consumed within the United Kingdom, and therefore should include most potential substitutes for salmon.

JEL Classification: C32; C22; D12.

Key words: Demand, salmon, whitefish, shellfish, AIDS, elasticities



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## Introduction

Within the United Kingdom (UK), food consumption changed substantially in the 1980s, a period which witnessed the lowest level of fish consumption for over 40 years. The change in consumption was generally attributed to the "consumption revolution" - a term used to explain the fundamental changes in the attitude and social behaviour of British consumers (Ritson and Hutchin, 1990). A wider range of choice of fish was available to consumers as a consequence of technological improvements in aquaculture and harvesting methods of wild species. The effect was a growth in apparent consumption above domestic production for many species, the reduction in price of some species and stabilisation in the prices of others. Wider choice, regular supplies and greater available volumes of formerly seasonal fish such as salmon in the market has benefited consumers in the form of reduced prices. The resultant effect on demand was greater choice across species and product forms, raising the question of how the demand interdependencies have changed.

Factors that will have influenced the consumption of fish and fish products in general include population growth, economic growth resulting in higher purchasing power, and social factors such as traditional food consumption patterns. The development and degree of sophistication of food production, processing, distribution and positive advertising campaigns will also impact the level of demand for fish. Over time, traditional fish consumption patterns may change as a result of changes in social conditions such as lifestyles and family structure. Attitudes towards food (fish) may also change due to greater health consciousness and greater exposure to fish arising from international travel.

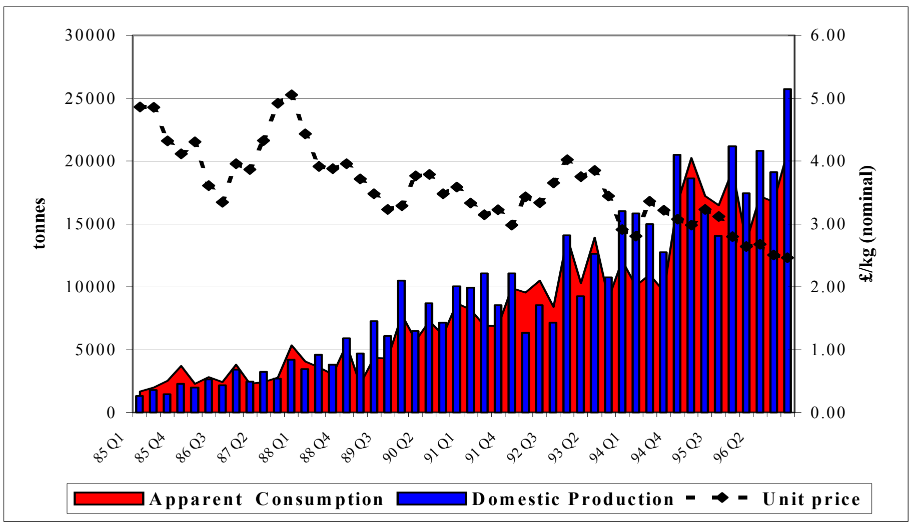
### *Farmed Salmon*

The production of Atlantic salmon in the UK has risen almost every year since the industry's inception in the 1960's. UK production of Atlantic salmon in the last decade increased rapidly from an output level of just under 7,000 tonnes in 1985 to over 83,000 tonnes in 1996 (SOAEFD). This implies an average annual growth rate of 21.6%. The rapid increase in productivity since the mid-1980s can be attributed to improved technology and husbandry, along with advances in disease and pest control.

The principal outlet for UK salmon is the domestic market, which has grown considerably as a result of increased availability and falling prices. Farmed Atlantic salmon is now the third most popular seafood in the UK, after cod and haddock, and accounts for 15% of all fresh and chilled fish consumed in the UK (Aquaculture Magazine, 1999). The initial increases in production due to rapid expansion of production capacity in both the UK and abroad was not followed by a similar outward shift in demand for salmon during the 1980s and 1990s. Consequently, supply increases were accompanied by a general and continuous fall in nominal salmon prices to the levels of other common marine harvested species in the market, and leading to increased price competition.

Apparent consumption did however grow at an annual average of 17.8% between 1985 and 1996, though still almost 4 percentage points below the rate of average output growth of the domestic industry. Production levels decreased between 1992 and 1993, both because of high incidences of disease and the Braer oil disaster. The increase in apparent consumption may be explained in part by a drop in the proportion of total production for export, which fell from 60% in the early 1980s to below 40% in 1996. It is reported that as much as 70% of total production now goes to the domestic market, competing directly with imports from Norway and the Faroe Isles (Sheal, Clay and Pascoe, 1998). Apparent consumption of salmon in the UK reveals a marked seasonal pattern with increases in consumption in the fourth quarter (Figure 1).

**Figure 1 Quarterly Production, Consumption and Price for Farmed Atlantic Salmon**



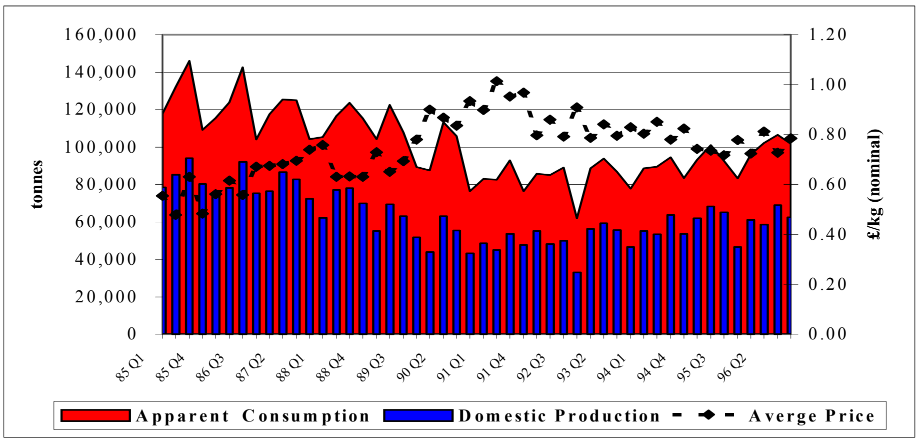

Source: SSB, SOAEFD

***Wild caught whitefish and shellfish***

Apparent consumption of whitefish also outpaced domestic production in the period 1985 through 1996 (Figure 2). This can be attributed to declining domestic landings of the two predominant species of haddock and cod, which may itself be partly due to the increased export of domestic landings[1] and the relatively tougher domestic regulation regime on catches. Imports are increasingly filling the gap between demand and supply of whitefish in the UK, created by a situation of declining landings volume and increasing consumption (Sheal, Clay and Pascoe, 1998). Since the early 1990s, domestic landings of wild catches appears to have improved, due mainly to the increased landings of monkfish.

In general, average unit values of whitefish species showed an increasing trend up to 1992, after which nominal values showed some degree of stability. The rising unit values during the first seven years of the period under review were mainly because of the increasing value of monkfish, which may have countered the overall decrease in other whitefish prices.

**Figure 2 Quarterly Production, Consumption and Prices for Selected* Whitefish**

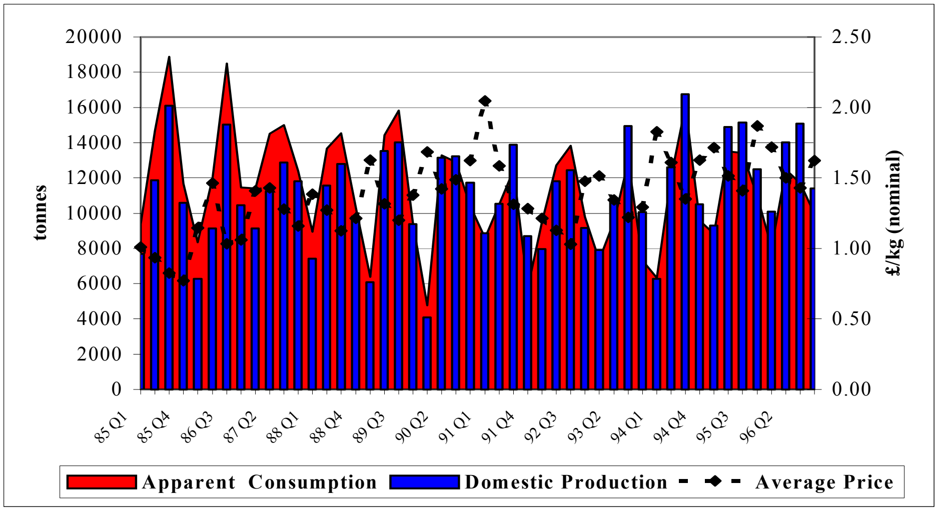



Source: MAFF, SOAEFD *includes cod, haddock, saithe, whiting, plaice

The UK seems to rely heavily on imports to meet its consumption needs for shellfish in the 1980s, as apparent consumption exceeded domestic production for most of the period (Figure 3). From the beginning of the 1990s however, there seemed to be a turn-around in domestic production, bring landings volumes above consumption volumes for most of the period up to end 1996. The main species of shellfish landed in the UK is nephrops (Norwegian lobster). Average prices showed an increasing trend over the period 1985-97, although there were wide seasonal variations.

[1] Monkfish, saithe, pollack and sole are the most predominant exports.

**Figure 3 Quarterly Production, Consumption and Price of Selected* Shellfish**




Source: MAFF, SOAEFD *includes nephrops, scallops, shrimp

Previous studies of demand interactions between salmon and wild-caught fish species in the U.K. are non-existent. However, quite a few papers have been dedicated to the study of fish and fish products, for example Banks (1984), Burton and Young (1992a, 1992b), and Duffy (1994). These studies were not species specific in approach and thus treated fish as an aggregate product. Therefore, little is known about the exact interaction between the various fish species in the U.K. market. With the changes occurring in the availability and prices of wild-caught fish, and the rapid increase in salmon production, it is worthwhile to examine the impact that the increased presence of salmon has had on the structure of fish demand in the U.K. The next section of this report develops the demand model for examining the relationship between fish species, followed by a section reporting the results of the models. Finally, some conclusion regarding demand interactions of fish species in the U.K. are given.

## Demand Analysis

Demand theory suggests that the aggregate demand for a product (i.e. salmon) at time $t$ depend on income, the price of salmon, the price of related commodities, and consumer taste and preferences. Suppose this is represented by a functional relationship as follows:

$$x_{1t} = f(p_{1t}, p_{2t} .......p_{nt}, y_t) \tag{1}$$

Where $x_{1t}$ is the quantity of salmon demanded at time $t$, $p_{1t}$ is the price of salmon at time $t$, $p_{it}$ ($i$ = 2, …, $n$) is the price of related goods at time $t$, and $y_t$ is income at time $t$. In a double log functional form, equation (1) can be expressed as

$$\ln x_{it} = \alpha + \sum_{j=1}^{n} \xi_j \ln p_{jt} + \eta \ln y_t + \varepsilon_t \tag{2}$$

where, $\alpha$, $\xi_j$ and $\eta$ are preference parameters which directly measure the own-price, cross-price and income elasticities of demand, and where $\varepsilon_t$ is a stochastic disturbance term.

The static demand equation as defined in equation (2) assumes instantaneous adjustment of consumption to changes in any of the independent variables. This assumption may not always hold however. Shifts in consumer tastes and preferences may affect the slope or the position of the demand curve or there may be rigidities in consumers' adjustments to price and income changes. Time lags and logistic delays in catch and distribution may also affect availability, and hence consumers' allegiance to a product, although this is probably of minor importance for food commodities which are consumed fresh (George and King, 1971). As a result of these influences, many applied economists have found it necessary to incorporate dynamics into demand models by including lagged consumption. The inclusion of $\ln x_{1t-1}$ as an extra explanatory variable in the model makes current consumption dependent on the previous period's consumption and thus accounts for habit formation.

***Specification of Demand Models***

In empirical demand studies, the choice and specification of a suitable demand model is crucial. The specification problems specific to demand analysis for perishable goods such as fish are the endogeneity of price and of quantity. It can be argued that the endogeneity of price or quantity in a specified demand model depends to a larger extent on the characteristics of the market and the interaction between quantity demanded and supplied. Where biological factors and fishery regulations determines the supply of fish as in the case of wild fisheries, Bird (1986) has argued for the suitability of an inverse demand model. Inverse demand models are built on the assumption that quantity and income explain price, thus price is treated as an endogenous variable.

Quantity dependent models are the most commonly used for the modeling of demand for farmed species. This is a primarily due to the possibility of the endogeneity of quantity supplied. In cultured fisheries, there is greater flexibility in harvesting the fish, therefore the farm-gate price is an important factor determining harvest rates and implies that fish farmers can adjust supply according to prevailing market conditions (i.e. supply is elastic) (Bjørndal, Salvanes and Andreassen, 1992). To avoid statistical inconsistency, Barten and Bettendorf (1989) have suggested that variables on the right hand side of demand equations (independent variables) should be those that are not controlled by the decision-maker. In this case, the farmer is the decision-maker who determines whether prices are favorable enough to harvest. As we are considering demand interactions between wild fish and salmon (cultured fish), the supply side of which shows some price sensitivities, a model where price explains quantity supplied and expenditure on fish may be a relevant option.

The notion of the exogeneity of price was statistically tested using the Hausman test. The null hypothesis $H_0$: the price of salmon is exogenous was tested against the alternative $H_A$: prices are endogenous. Using real private final consumption as an instrument, the estimated test statistics is 5.60 and is distributed as $\chi^2$. The critical value at 1% with one degree of freedom is 6.63. Therefore, we fail to reject the null hypothesis, implying that prices can be treated as exogenous. This is accordance with studies done by Asche, Salvanes and Steen, (1997), Bjørndal, Salvanes and Andreassen (1992), Bjørndal, Salvanes and Gordon (1994), and Burton and Young (1992a, 1992b). We therefore specify our models with quantity demanded as the dependent variable.

***Single Equation Model***

Assuming that quantity supplied is predetermined, we specify a linear demand model for salmon as

$$Q_{it} = f\left(P_{it}, P_{jt}, y_t, Q_{it-1}, S_{kt}, \varepsilon_t\right) \tag{3}$$

where:

$Q_{it}$ = quantity of salmon ($i$) demanded in period $t$;

$P_{it}$ = real price of salmon in period $t$;

$P_{jt}$ = real price of substitute products; $j \neq I$, $\forall\, j = 1, \ldots, n$;

$y_t$ = real income (GNP deflated by Retail Price Index for food)

$Q_{it\text{-}1}$ = lagged consumption of salmon;

$S_{kt}$ = seasonal dummies.

Prices are unit values, obtained from official data on domestic landings volume and value (SOAEFD, MAFF and DANI). The data in this study are quarterly ex-vessel prices and quantities from 1985:1 through 1996:4. All prices were deflated by the Retail Price Index for food (January 1987=100).

Two demand equations for salmon are estimated in this study; a "whitefish" model and a "shellfish" model. This is done for two reasons: (a) to accommodate the relatively low number of observations in the data set ($n$ = 48); and (b) to determine the market relationships between salmon and the main seafood products in the UK market. From the market delineation study (Clay & Fofana, 1999), it was found that the whitefish species of cod, monkfish, plaice, whiting, and saithe formed bivariate cointegrating relationships with salmon. In the shellfish group, mussels, nephrops, scallops and shrimp were each found to be cointegrated with salmon. These species are therefore assumed to be part of the same market as salmon, and are included as substitutes in the respective models.

The choice of an appropriate functional form in demand modeling is an empirical question that needs to be addressed. The criteria in choosing between alternative functional forms are economic theory considerations, prior empirical work, interpretation of results, and computational convenience. In single demand equation modeling, some of the more common alternative functional forms are linear, semi-logarithmic, inverse-logarithmic, and double-logarithmic specifications. In this study, the functional forms that are tested are linear and double-logarithmic models as shown below.

*Linear* $$Q_t = \alpha + \delta Q_{t-1} + \beta_i P_{it} + \sum_{j=1}^{n} \beta_j P_{jt} + \eta Y_t + \sum_{k=1}^{m} \gamma_{ik} S_{kt} + \varepsilon_t \qquad (4)$$

*Double-log* $\ln Q_t = \alpha + \delta \ln Q_{t-1} + \beta_i \ln P_{it} + \sum_{j=1}^{n} \beta_j \ln \mathrm{P}_{jt} + \eta \ln \mathrm{Y}_t + \sum_{k=1}^{m} \gamma_{ik} S_{kt} + \varepsilon_t$ (5)

There are many ways to test for an appropriate functional form in single equations, but the Box-Cox transformation is the most popular method applied in empirical research and is used in this work to identify the appropriate functional form of the model.

All potential variables to enter the final model are defined according to the following Box-Cox transformation:

$$z_t(\lambda) = \frac{\mathrm{Z}^{\lambda} - 1}{\lambda}$$

where $\lambda$ defines the functional form to be adopted and is estimated via a maximum likelihood technique. If $\lambda$=1, the functional form is linear in specification. If, on the other hand, $\lambda$=0, the functional form takes a double-logarithmic transformation.

Box-Cox regression was performed on equation (4) for both the whitefish and the shellfish group, and the null hypothesis that the model is linear was tested. The test statistic is calculated from the following formula: $2\left[L(\tilde{\lambda}) - L(\lambda = 1)\right]$. This test statistic is compared to a $\chi^2_{(1)}$ distribution. Table 1 summarizes the test results for both equations. From the results, we can reject the null hypothesis that the correct model specification is linear, but cannot reject the null when ($\lambda$=0), indicating a double-log specification for the demand model.

**Table 1 Box-Cox Regressions for Model Specification**

| Model | λ | $H_0$: (λ=1) *linear* Test-statistic | Result | $H_0$: (λ=0) *double-log* Test-statistic | Result |
|---|---|---|---|---|---|
| **Whitefish** | 0.160 | 20.676 | Reject | 0.824 | Fail to Reject |
| **Shellfish** | 0.040 | 24.238 | Reject | 0.038 | Fail to Reject |

Critical value ($\chi^2_{(1)}$) = 3.84

Using the double log specification as given in equation (5) above, a simple linear demand model was estimated for salmon using ordinary least squares. Initially, the models were run including all 6 species of whitefish as substitutes (cod, haddock, monkfish, saithe, whiting, plaice) within the *Whitefish* model, and all 4 species of shellfish (mussels, nephrops, scallops and shrimp) within the *Shellfish* model. The results of the models are reported in Table 2. The results are disappointing, with few significant estimates and most 'substitute' products exhibiting the wrong sign. For the whitefish model, cod, haddock and monkfish appears to be complements to salmon, although the coefficient estimates are not significant. The coefficients for the saithe, whiting and plaice price variables indicate substitute relationships with salmon, although none of the estimates are significant. There does appear to be significant and positive habit formation on the part of consumers for the demand for salmon. The income elasticity is high at 2.836 indicating that salmon is perceived to be a luxury product in relation to other whitefish products.

The shellfish model shows similar results. Mussel is the only product that appears to be a possible substitute for salmon, however the coefficient cannot be said to be different from zero. All other shellfish products appear to be complements (none are significant at 5% however). There is again significant and positive habit formation on the part of consumers for the demand for salmon. The income elasticity (1.644) indicates that salmon is perceived to be a luxury product in relation to other shellfish products, although not to the same extent as compared to whitefish.

**Table 2 Double-log estimates of salmon demand**

| | WHITEFISH | | SHELLFISH | |
|---|---|---|---|---|
| **VARIABLE** | **Estimated Coefficient** | **Standard Error** | **Estimated Coefficient** | **Standard Error** |
| $P_{SAL}$ | -0.304 | 0.247 | -0.518* | 0.241 |
| $P_{COD}$ | -0.568 | 0.459 | | |
| $P_{HAD}$ | -0.070 | 0.286 | | |
| $P_{MON}$ | -0.039 | 0.493 | | |
| $P_{SAI}$ | 0.231 | 0.282 | | |
| $P_{WHI}$ | 0.083 | 0.380 | | |
| $P_{PLA}$ | 0.300 | 0.378 | | |
| $P_{MUS}$ | | | 0.073 | 0.093 |
| $P_{NEP}$ | | | -0.164 | 0.296 |
| $P_{SCA}$ | | | -0.359 | 0.206 |
| $P_{SHR}$ | | | -0.103 | 0.149 |
| $QSAL_{t-1}$ | 0.553* | 0.151 | 0.477* | 0.158 |
| RGNP | 2.836* | 1.251 | 1.644 | 0.997 |
| D1 | -0.577* | 0.144 | -0.429* | 0.141 |
| D2 | -0.371* | 0.169 | -0.273* | 0.104 |
| D3 | -0.461* | 0.103 | -0.481* | 0.097 |
| CONSTANT | -29.655* | 14.700 | -13.899 | 11.67 |
| $R^2$ | 0.8605 | | 0.8580 | |
| D-W | 2.0671 | | 1.8825 | |

* indicates significant at 95%

The problems of insignificant estimates and incorrect signs within these models suggest that there may be a problem with auto-correlation. There are many problems that may have led to presence of auto-correlation in the preferred double log model such as specification bias either in the form of excluded variables or incorrect functional form of the model (Alston and Chalfant, 1991). In addition, autocorrelation may be present due to the number of lags in the model or from the presence of non-stationary variables.

There are many problems associated with single demand model estimation. One such problem is the aggregation of data. Aggregate demand depends on the distribution of aggregate income unless special assumptions hold. This can be incorporated into demand models by including additional variables such as income dispersion in the population and income dispersion over time. Data availability for such variables however is normally a problem and therefore the inclusion of these types of variables in empirical work so far has been disregarded.

Another problem often found in single equation demand models is that the income effect is too large. This is due to the use of income variables, which are aggregates of total consumer spending in an economy, or monetary value of the total productive processes in the economy (GNP). As consumer expenditure on any one good is likely to account for only a small proportion of this total, the estimated income effect should be much smaller.

Single demand equations also omit the effects of price changes in other goods and services in the economy. The effect of these omitted variables becomes part of the error term, which may render estimates biased. An *ad hoc* response has been to deflate the included prices and income by a consumer price index, thus implicitly including an index for the prices of "*all other goods*". The underlying assumption is that the relative prices of all goods making up the index remain unchanged over time. Furthermore, with the exception of homogeneity and negativity, most of the restrictions on models that correspond to demand theory cannot be imposed or tested in single demand estimation. In the next section an Almost Ideal Demand System (AIDS) is specified.

*Demand System*

The most common demand systems used in applied work are either the Rotterdam model or the Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980a, 1980b). The AIDS model has been proven to closely approximate any demand system, it allows for the consistent aggregation of individual demand curves to a market demand curve, it does not impose additive preferences, and it precisely satisfies the axiom of choice. In addition, the AIDS model has gained widespread appeal in both direct applications and extensions to more complex application (see for example Asche *et al* (1997); Eales and Unnevehr (1994)). Owing to these attributes, the AIDS model is the most popularly used demand system in applied economic research in recent times.

The model is built on the basic assumption that commodities are weakly separable from non-related goods. This implies that the goods can be partitioned into subsets such that the marginal rate of substitution involving two products in the same subset depends only on the goods in that subset alone, and is independent from any other product outside of the group[2].

In the AIDS model, consumer preferences belong to the Price Independent Generalized Logarithmic class (PIGLOG). This characterizes consumer preferences to satisfy inter-temporal separability such that once a consumption decision is taken, the remaining issue for the consumer is to allocate spending among the goods in the system. The cost or expenditure function to the consumer can be given as follows

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[2] The marginal rate of substitution (MRS) of two goods (say X and Y) is defined as the number of units of commodity X that must be given up in exchange for extra units of commodity Y so that the consumer maintains the same level of satisfaction.

$$\ln C(u,p) = (1-u)\ln[a(p)] + u\ln[b(p)] \tag{6}$$

which defines the minimum expenditure necessary to attain a specific utility level at given prices. From equation (6), $a(p)$ and $b(p)$ are homogenous functions of prices and are given by

$$\ln[a(p)] = \alpha_0 + \sum_k \alpha_k \ln p_k + \frac{1}{2}\sum_k\sum_j \gamma_{kj} \ln p_j \qquad \text{and}$$

$$\ln[b(p)] = u\beta_0 \prod_k p_k{}^{\beta_k}$$

The demand function can be derived directly from equation (6) by differentiating with reference to *p*. After some mathematical manipulation, this yields the share equation specified as a function of its own price, the price of other goods in the system and the real total expenditure on the group of goods. The AIDS model corresponding to equation (6) is written as:

$$w_{it} = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln P_{jt} + \beta_i \ln\left(\frac{X_t}{P_t}\right) \tag{7}$$

where $w_{it}$ is the budget share of the $i^{th}$ commodity, $P_{jt}$ are prices of the $j^{th}$ commodity in the bundle, $X_t$ is total expenditure on all commodities in the system and $P_t$ is the index of prices. The index of prices $P_t$ is assumed to be a function of commodity prices and is defined as a translog price index of the form:

$$\ln P_t = \alpha_0 + \sum_j \alpha_k \ln P_k + \frac{1}{2}\sum_j\sum_k \gamma_{jk} \ln P_j \tag{8}$$

Equation (8) is linear except for the translog price index ln $P_t$. Using equation (8) to estimate the price index leads to computational difficulties. To keep the demand system linear, Stone's price index is commonly used as an approximate to the translog price index. However, the Stone index has been proven to be inappropriate as it leads to inconsistent parameter estimates (Buse, 1994; Moshini, (1995). Moshini has argued that this is due to the fact that the Stone index is invariant to the unit of measurement and has suggested the Laspeyres version of the Stone's price index. This is known as the 'corrected' Stone index, and is written as:

$$\ln \mathrm{P}_t^s = \sum w_{it} \ln\left(\frac{p_{it}}{p_i^0}\right) \tag{9}$$

where $p_i^0$ is the mean of the series used as the base period. Asche and Wessel (1997) have shown that when prices are scaled by their mean, the linear AIDS is equivalent to the AIDS model. In constructing Stone's price index, lagged budget shares are used to avoid simultaneity in the equations (Eales and Unnevehr, 1988) of the form:

$$\ln P_t = \sum_j w_{it-1} \ln p_{jt} \tag{10}$$

AIDS models that use Stone's index are known as linear approximate almost ideal demand systems (LA/AIDS). Deaton and Muellbauer noted that with this approximation, the system of equations in (7) will be excellent as long as prices are collinear.

To keep the model consistent with economic theory, the parameters are constrained such that the homogeneity, adding-up and symmetry conditions hold. Homogeneity implies that consumers' decisions are driven by real rather than relative prices. For homogeneity to hold, the estimated price parameters in each equation must add up to zero to ensure the absence of money illusion in the behavior of consumers. The adding-up property is satisfied by the construction of the data. In such cases, the budget shares add up to unity which makes the covariance matrix for the demand system singular. To circumvent this problem, one equation is excluded. The omitted equation can then be recovered by applying the adding-up condition. The symmetry condition requires that the effect of a change in the price of a good *i* on the demand of good *j* within the system is the same, and the reverse of this is also true. Restrictions on the parameters to be estimated are imposed as follows:

$$\sum_{i=1}^{n}\alpha_i = 1 \qquad \sum_{i=1}^{n}\gamma_{ij} = 0 \qquad \sum_{i=1}^{n}\beta_i = 0 \qquad \text{(Adding up)}$$

$$\sum_{i=1}^{n}\gamma_{ij} = 0 \qquad \text{(Homogeneity)}$$

$$\gamma_{ij} = \gamma_{ji} \qquad i \neq j \qquad \text{(Symmetry)}$$

The homogeneity and symmetry restrictions are empirically testable and must be imposed on the estimated parameters, but the adding-up condition is not. Therefore, the adding-up condition must be automatically satisfied during the construction of the data. To avoid a singular covariance matrix, one equation must be deleted before estimation.

While the use of linear approximate almost ideal demand system as proxy for the true almost ideal demand system model is not necessarily an inferior approach, it has implications for computing elasticities (Green and Alston, 1990). The uncompensated and compensated elasticities for commodity *i* with respect to commodity *j*'s price for LA/AIDS are calculated as follows

Uncompensated: $$\phi_{ij} = \frac{\gamma_{ij}}{w_i} - \beta\frac{w_j}{w_i} - \delta, \quad \delta = 1, i = j, \delta = 0, i \neq j$$

Compensated: $\phi_{ij} = \frac{\gamma_{ij}}{w_i} + w_j - \delta,\ \delta = 1,\ i = j,\ \delta = 0,\ i \neq j$

Expenditure: $\eta_i = 1 + \frac{\beta_i}{w_i}$

Calculating elasticities, the budget shares are ideally the predicted shares at the estimation point. However, Chalfant (1987) indicates that the use of the corresponding sample share closely approximates the predicted shares, and that these can be used in empirical work. This approach was adopted in this work.

Two demand systems were estimated using the specification given in equation (7); one for the whitefish group identified in the market delineation analysis and one for the shellfish group. For each demand system, summary statistics of the budget shares, $R^2$ values and Ljung-Box tests for autocorrelation for the ($n$-1) equations are reported. Estimated elasticities (uncompensated and compensated) are reported separately for the two demand systems. Parameter estimates are not reported in this section but are included in appendix (see Appendix I).

The Whitefish

The whitefish system contains wetfish species found to have a market relationship with salmon in the market delineation analysis and includes cod, monkfish, saithe, whiting, plaice and salmon. Haddock, while an important whitefish species in terms of apparent consumption, was not integrated with salmon, nor with the whitefish grouping of cod, saithe, whiting and plaice. Monkfish was found to have a strong relationship with salmon, and through salmon, with the other whitefish species.

Descriptive statistics for this system are shown in Table 3. Cod is by far the most important species within this market, commanding a 65% budget share within the whitefish system. The rest of the fish in this system can be considered to be of minor importance. In terms of relative importance however, whiting holds the number two position with a budget share of 10.3%, closely followed by plaice with a 9.1% budget share. If salmon is part of this system, it has a 7.2% budget share. The $R^2$ values are satisfactory. The autocorrelation tests do not reveal any problems with dynamic mis-specification in the equations for cod, whiting or plaice. For monkfish, the null hypothesis of no autocorrelation can be rejected at the 5% level, but not at a 1% level. There is however a problem in the equation for salmon as the null hypothesis can be rejected at all significance levels.

**Table 3 Descriptive statistics for the Whitefish demand system**

| | Cod | Monkfish | Saithe | Whiting | Plaice | Salmon |
|---|---|---|---|---|---|---|
| Budget Share | 0.650 | 0.024 | 0.059 | 0.103 | 0.091 | 0.072 |
| | (0.061) | (0.016) | (0.019) | (0.021) | (0.017) | (0.037) |
| $R^2$ | 0.696 | 0.731 | 0.171 | 0.511 | 0.405 | |
| L-B(1) | 3.57 | 5.52* | 0.10 | 2.93 | 3.21 | |

Salmon equation dropped in estimation procedure.
*indicates significant at 5% level and ** indicates significant at 1% level

Both compensated and uncompensated elasticities are reported for the demand system, although the compensated elasticities are perhaps of more relevance as they show the pure substitution effect. This is because any change in the relative demand for two products due to a change in relative prices (i.e. the income effect) has been compensated for. The compensated elasticities are summarised in Table 4 below.

**Table 4 Compensated elasticities of demand – Whitefish system**

| | Equation | | | | | |
|---|---|---|---|---|---|---|
| | Cod | Monkfish | Saithe | Whiting | Plaice | Salmon |
| Cod | **0.078** | 0.371 | 0.172 | -0.115 | -0.795* | 0.201 |
| | **(0.067)** | (0.548) | (0.329) | (0.183) | (0.167) | (0.315) |
| Monkfish | 0.014 | **-0.777** | -0.041 | 0.077 | 0.500* | -0.577* |
| | (0.020) | **(0.589)** | (0.130) | (0.091) | (0.074) | (0.106) |
| Saithe | 0.016 | -0.101 | **-0.401** | -0.030 | 0.089 | 0.152 |
| | (0.030) | (0.316) | **(0.264)** | (0.103) | (0.105) | (0.165) |
| Whiting | -0.018 | 0.326 | -0.053 | **-0.490*** | 0.100 | 0.674* |
| | (0.029) | (0.389) | (0.179) | **(0.145)** | (0.094) | (0.145) |
| Plaice | -0.112* | 1.892* | 0.138 | 0.089 | **-0.710*** | 1.041* |
| | (0.023) | (0.281) | (0.164) | (0.083) | **(0.116)** | (0.148) |
| Salmon | 0.022 | -1.712* | 0.185 | 0.469* | 0.816* | **-1.491*** |
| | (0.035) | (0.313) | (0.201) | (0.101) | (0.116) | **(0.265)** |

*indicates significant at 5% level and ** indicates significant at 1% level

All of the own-price elasticities of the whitefish species are negative. The exception to this is the estimated value for own-price elasticity of cod, however the estimate is not statistically significant. The own-price elasticities for the other whitefish species range from –0.401 to-0.777 indicating that demand for these species is relatively inelastic while salmon has an own-price elasticity of –1.491 which indicates a highly elastic demand for salmon.

Examining the cross-price elasticities, we do not find any statistically significant substitutes for cod. For those species which show a substitute relationship (monkfish, saithe and salmon), the estimated cross-price elasticities are very close to zero. Plaice shows a significant relationship with cod, although it is a complementary relationship.

The cross-price elasticities for monkfish indicate a strong substitute relationship with plaice, and a weaker (although statistically insignificant) relationship with cod and whiting. A strong complementary relationship is shown with salmon, which is not expected given that these two products are both considered “high-value” fish and would therefore be expected to be substitutable.

No significant substitutes were found for saithe, although there are indications that cod is a weak substitute. The cross-price elasticities for plaice and salmon indicate a substitute relationship, but the values are very close to zero. For whiting, salmon is the only significant substitute, with a cross-price elasticity of 0.469. Plaice and monkfish also appear to be weak substitutes. Salmon also appears to have a significant substitute relationship with plaice, as does monkfish. Whiting and saithe show as substitutes for plaice as well, although these estimates are small in value not significant.

Examining the cross-price elasticities for salmon, whiting and plaice are both found to be significant substitutes, while saithe and cod are insignificant. Monkfish again appears as a complement good to salmon. This result may be due to the fact that monkfish has such a low budget share within the whitefish system.

**Table 5 Uncompensated elasticities of demand – Whitefish system**

| | **Equation** | | | | | |
|---|---|---|---|---|---|---|
| | Cod | Monkfish | Saithe | Whiting | Plaice | Salmon |
| Cod | -0.777* | -2.076* | -0.267 | -0.293 | -0.593* | 0.072 |
| | (0.055) | (0.569) | (0.341) | (0.172) | (0.183) | (0.329) |
| Monkfish | -0.018 | -0.868 | -0.058 | 0.070 | 0.508* | -0.582* |
| | (0.021) | (0.584) | (0.131) | (0.091) | (0.075) | (0.110) |
| Saithe | -0.062* | -0.323 | -0.440 | -0.047 | 0.107 | 0.140 |
| | (0.031) | (0.312) | (0.261) | (0.101) | (0.105) | (0.164) |
| Whiting | -0.153* | -0.061 | -0.123 | -0.518* | 0.132 | 0.653* |
| | (0.032) | (0.418) | (0.191) | (0.150) | (0.100) | (0.160) |
| Plaice | -0.232* | 1.548* | 0.076 | 0.064 | -0.682* | 1.023* |
| | (0.025) | (0.305) | (0.169) | (0.088) | (0.117) | (0.144) |
| Salmon | -0.072 | -1.982* | 0.137 | 0.450* | 0.838* | -1.505* |
| | (0.040) | (0.358) | (0.228) | (0.115) | (0.131) | (0.299) |
| Expenditure | 1.315* | 3.762* | 0.675 | 0.273 | -0.312 | 0.198 |
| | (0.083) | (0.747) | (0.487) | (0.240) | (0.280) | (0.596) |

*indicates significant at 5% level and ** indicates significant at 1% level

With the uncompensated elasticities, the expenditure effect is also taken into account. The expenditure elasticity is the expected sign for all of the whitefish species with the exception of plaice, although this estimate is statistically insignificant. The remaining whitefish species appear to be normal goods, although the expenditure elasticity for cod is relatively high, which may be a result of its large budget share. Monkfish appears to be a luxury good.

The expenditure elasticity for salmon is very close to zero, and insignificant. This indicates that the demand for salmon may not be influenced by the demand for other whitefish, as there is no impact on the demand for salmon when a change occurs in the distribution of expenditure among the whitefish species.

The uncompensated cross-price elasticities do not differ substantially, in terms of magnitude or sign, from the compensated elasticities. Overall, the same relationships are found with salmon appearing to be a substitute for whiting and plaice or and a complement to monkfish. The only noticeable difference in the results are for the monkfish - cod relationship, where cod appears to be a significant complement to monkfish when looking at uncompensated cross-price elasticities, but a weak substitute once the demand function is compensated for the income effect. This is likely due to the very high budget share allocated to cod, and the very low budget share for monkfish.

<u>Shellfish</u>

The shellfish system contains shellfish species found to have a market relationship with salmon in the market delineation analysis and includes mussels, nephrops, scallops, and shrimp along with salmon.

Descriptive statistics for this system are shown in Table 6. Cod is by far the most important species within this market, commanding a 65% budget share within the whitefish system. The rest of the fish in this system can be considered to be of minor importance. In terms of relative importance however, whiting holds the number two position with a budget share of 10.3%, closely followed by plaice with a 9.1% budget share. If salmon is part of this system, it has a 7.2% budget share. The $R^2$ values are satisfactory for highly disaggregated series. The autocorrelation tests do not allow us to reject the null of no autocorrelation of any of the shellfish equations. Care must therefore be taken in interpreting the results of this system.

**Table 6 Descriptive statistics for the Shellfish demand system**

| | Mussels | Nephrops | Scallops | Shrimp | Salmon |
|---|---|---|---|---|---|
| Budget Share | 0.231 | 0.229 | 0.121 | 0.135 | 0.283 |
| | (0.117) | (0.071) | (0.042) | (0.067) | (0.107) |
| $R^2$ | | 0.588 | 0.547 | 0.566 | 0.482 |
| L-B(1) | | 11.08** | 8.26** | 9.14** | 12.58** |

*Scallop equation dropped in estimation procedure.
*indicates significant at 5% level and ** indicates significant at 1% level

Compensated elasticities are summarised in Table 7 below. All of the own-price elasticites are of the correct sign, with salmon demand showing the highest sensitivity to price changes. Examining the cross-price elasticities, salmon appears to be a significant substitute for each of shellfish species. The only other significant substitute relationship found in this system is between scallops and mussels. Shrimp and scallops show a substitute relationship, although we cannot reject that the estimate is different from zero.

**Table 7 Compensated elasticities of demand – Shellfish system**

| | Equation | | | | |
|---|---|---|---|---|---|
| | Mussels | Nephrops | Scallops | Shrimp | Salmon |
| Mussels | -0.096 | -0.112 | 0.204* | -0.301* | 0.226* |
| | (0.061) | (0.070) | (0.092) | (0.096) | (0.056) |
| Nephrops | -0.111 | -0.153 | -0.266 | -0.120 | 0.385* |
| | (0.069) | (0.194) | (0.191) | (0.180) | (0.076) |
| Scallops | 0.106* | -0.140 | -0.621* | 0.187 | 0.202* |
| | (0.048) | (0.101) | (0.163) | (0.111) | (0.049) |
| Shrimp | -0.176* | -0.071 | 0.210 | -0.275 | 0.242* |
| | (0.056) | (0.106) | (0.124) | (0.179) | (0.067) |
| Salmon | 0.277* | 0.476* | 0.473* | 0.508* | -1.056* |
| | (0.069) | (0.094) | (0.115) | (0.141) | (0.107) |

*indicates significant at 5% level and ** indicates significant at 1% level

Looking at the results in Table 8, we can see that the expenditure elasticities indicate that all of the products in the shellfish system are considered to be normal goods, with scallops and salmon showing relatively elastic demand with respect to expenditure. The expenditure elasticity for shrimp is very low, and is likely to be zero as it is statistically insignificant.

Without compensating for the income effect, salmon still appears to be a substitute for each of the shellfish species. However, only for shrimp is this relationship significant. For salmon, the cross-price elasticities for nephrops, scallops and shrimp are all very close to zero, and are insignificant. For all other products in the system, no significant substitute relationships were found.

**Table 8 Uncompensated elasticities of demand – Shellfish system**

| | Equation | | | | |
|---|---|---|---|---|---|
| | Mussels | Nephrops | Scallops | Shrimp | Salmon |
| Mussels | -0.251* | -0.327* | -0.166* | -0.318* | -0.124 |
| | (0.058) | (0.064) | (0.083) | (0.101) | (0.070) |
| Nephrops | -0.264* | -0.366 | -0.633 | -0.137 | 0.038 |
| | (0.092) | (0.212) | (0.207) | (0.211) | (0.101) |
| Scallops | 0.026 | -0.252* | -0.814* | 0.178 | 0.019 |
| | (0.061) | (0.109) | (0.179) | (0.127) | (0.062) |
| Shrimp | -0.266* | -0.196 | -0.007 | -0.285 | 0.038 |
| | (0.065) | (0.104) | (0.125) | (0.177) | (0.073) |
| Salmon | 0.088 | 0.213 | 0.020 | 0.487* | -1.485* |
| | (0.113) | (0.127) | (0.161) | (0.203) | (0.164) |
| Expenditure | 0.668* | 0.928* | 1.600* | 0.075 | 1.516* |
| | (0.247) | (0.257) | (0.334) | (0.399) | (0.314) |

*indicates significant at 5% level and ** indicates significant at 1% level

## *Concluding Remarks*

In this paper, we have investigated the demand relationships between salmon and a number of wild-caught whitefish and shellfish species. The demand equations were estimated both as single equation models and within an AIDS system framework.

Problems with autocorrelation were found in both approaches, although this was less of a problem in the systems approach then with the single-equation models.

Demand studies often encounter the problems of data aggregation as empirical work can only feasibly include a limited number of variables. Often assumptions are made concerning which species are substitute products for the product under examination, leading to *a priori* assumptions regarding market relationships and 'separability'. In this study, the inclusion of variables was determined on the results of the market delineation analysis of Clay and Fofana (1999). These results indicated that salmon had a long-run market relationship with the whitefish species of cod, monkfish, saithe, whiting and plaice and with the shellfish species of mussels, nephrops, scallops and shrimp. These groups contain the main seafood species consumed within the United Kingdom, and therefore should include most potential substitutes for salmon.

From the demand analysis, and the resulting elasticity estimates, it appears that salmon competes more directly within the shellfish system than the whitefish system. Within the shellfish system, salmon is a substitute for all four species, although the relationships are not particularly strong, with compensated cross-price elasticites ranging from 0.277 to 0.508.

Within the whitefish system, salmon does not appear to be a strong member of the group. It does appear to compete with whiting and plaice, but surprisingly not with cod. The disparity of the budget shares within this system may hide some of the relationships however, as cod dominates.

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# Appendix I

**Coefficient Estimates – Whitefish AIDS model**

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EQUATIONS (→)** | | | | | | | | | | | | | | |
| **WCOD** | | | **WMON** | | | **WSAI** | | | **WWHI** | | | **WPLA** | | |
| **Variable** | **Coef.** | **St.Error** | **Variable** | **Coef.** | **St.Error** | **Variable** | **Coef.** | **St.Error** | **Variable** | **Coef.** | **St.Error** | **Variable** | **Coef.** | **St.Error** |
| PCOD | 0.278* | 0.043 | PCOD | -0.007 | 0.013 | PCOD | -0.028 | 0.019 | PCOD | -0.079* | 0.019 | PCOD | -0.132* | 0.015 |
| PMON | -0.007 | 0.013 | PMON | 0.005 | 0.014 | PMON | -0.004 | 0.008 | PMON | 0.005 | 0.009 | PMON | 0.044* | 0.007 |
| PSAI | -0.028 | 0.019 | PSAI | -0.004 | 0.008 | PSAI | 0.032* | 0.016 | PSAI | -0.009 | 0.011 | PSAI | 0.003 | 0.010 |
| PWHI | -0.079* | 0.019 | PWHI | 0.005 | 0.009 | PWHI | -0.009 | 0.011 | PWHI | 0.042* | 0.015 | PWHI | 0.000 | 0.009 |
| PPLA | -0.132* | 0.015 | PPLA | 0.044* | 0.007 | PPLA | 0.003 | 0.010 | PPLA | 0.000 | 0.009 | PPLA | 0.018 | 0.011 |
| PSAL | -0.032 | 0.023 | PSAL | -0.043* | 0.008 | PSAL | 0.007 | 0.012 | PSAL | 0.041* | 0.010 | PSAL | 0.068* | 0.011 |
| EXP | 0.205* | 0.054 | EXP | 0.067* | 0.018 | EXP | -0.019 | 0.029 | EXP | -0.075* | 0.025 | EXP | -0.120* | 0.026 |
| S1 | 0.019 | 0.014 | S1 | -0.004 | 0.005 | S1 | 0.012 | 0.008 | S1 | -0.030* | 0.007 | S1 | 0.011 | 0.007 |
| S2 | 0.025 | 0.013 | S2 | -0.010* | 0.004 | S2 | -0.005 | 0.008 | S2 | -0.026* | 0.006 | S2 | 0.026* | 0.007 |
| S3 | -0.029* | 0.013 | S3 | -0.002 | 0.004 | S3 | -0.001 | 0.008 | S3 | -0.007 | 0.007 | S3 | 0.018* | 0.007 |
| System $R^2$ | | 0.9744 | | | | | | | | | | | | |
| $\chi^2$ (35) | | 175.92 | | | | | | | | | | | | |

**Coefficient Estimates – Shellfish AIDS model**

| EQUATIONS (→) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | WSAL | | | WNEP | | | WSCA | | | WSHR | |
| Variable | Coef. | St.Error | Variable | Coef. | St.Error | Variable | Coef. | St.Error | Variable | Coef. | St.Error |
| PSAL | -0.096* | 0.030 | PSAL | 0.044* | 0.021 | PSAL | 0.023 | 0.014 | PSAL | 0.030 | 0.019 |
| PMUS | -0.001 | 0.016 | PMUS | -0.079* | 0.016 | PMUS | -0.003 | 0.011 | PMUS | -0.072* | 0.013 |
| PNEP | 0.044* | 0.021 | PNEP | 0.142* | 0.044 | PNEP | -0.060* | 0.023 | PNEP | -0.047 | 0.024 |
| PSCA | 0.023 | 0.014 | PSCA | -0.060* | 0.023 | PSCA | 0.031 | 0.020 | PSCA | 0.009 | 0.015 |
| PSHR | 0.030 | 0.019 | PSHR | -0.047 | 0.024 | PSHR | 0.009 | 0.015 | PSHR | 0.080* | 0.024 |
| EXP | 0.146 | 0.089 | EXP | -0.017 | 0.059 | EXP | 0.072 | 0.040 | EXP | -0.125* | 0.054 |
| S1 | -0.107* | 0.035 | S1 | 0.035 | 0.023 | S1 | -0.032* | 0.015 | S1 | 0.033 | 0.021 |
| S2 | -0.167* | 0.040 | S2 | 0.077* | 0.028 | S2 | -0.083* | 0.019 | S2 | 0.015 | 0.025 |
| S3 | 0.008 | 0.035 | S3 | 0.007 | 0.024 | S3 | -0.063* | 0.016 | S3 | -0.017 | 0.021 |
| System $R^2$ | | 0.9837 | | | | | | | | | |
| $\chi^2$ (26) | | 197.68 | | | | | | | | | |