NHH

Norges
Handelshøyskole

Norwegian School of Economics
and Business Administration

Specification of Dynamic Demand Systems:

The Demand for Salmon in the European Union

by

Frank Asche

A dissertation submitted for the degree of dr. oecon.

Acknowledgements

I would like to thank the members of my committee, Kjell G. Salvanes, Trond Bjørndal and Cathy R. Wessells, whose valuable advice, support and encouragement I have benefitted from in my work on this dissertation.

In addition, I will express my gratitude to Richard W. Blundell, Helge Bremnes, Daniel V. Gordon, Tor H. Hauge, Torbjørn Lorentzen, Gordon Munro, Frode Steen, Leif T. Træen, Ragnar Tveterås, Terry J. Wales and Richard Yates, whose helpful comments I have benefitted from at various stages in the work on this dissertation. Thanks also to staff members at the Department of Economics, Norwegian School of Economics and Business Administration, the Centre for Fisheries Economics and at the Foundation for Research in Economics and Business Administration for valuable support. I also would like to thank staff members at the Department of Economics and the Fisheries Centre at the University of British Columbia, where I spent the year 1994, for making my stay a very pleasant and rewarding one.

Financial support from the Norwegian Research Council made both this work and the stay at at the University of British Columbia possible.

Finally, I would like to thank my wife, Tina, and my daughter, Anne Lene, for support and endurance during this work.

Contents

Figures

Tables

1: INTRODUCTION

The primary purpose of this dissertation is to study econometric specifications of demand equations consistent with economic theory. These specifications will be used to analyse the demand structure in the European Union salmon market. Special attention will be given to dynamic specification, as several studies have shown that it is important to include appropriate dynamics to obtain specifications in accordance with economic theory. Accordingly, only time series data will be used. Issues concerning use of cross section data in demand analysis and aggregation will be regarded as out of scope.

Two different approaches to demand analysis are common in the literature, single equation specifications and system specifications. The two approaches differ to the extent the estimated demand equations may be related to the consumer theory. In the single equation approach, one uses the first order conditions from the consumer's optimisation problem, which predicts a relationship between quantity demanded for a product, the own price, the price of substitutes and income. The demanded quantity (or price) of a product is then regressed on the other variables with an arbitrarily chosen functional form.

In applied work with single equation demand specifications, functional forms which are linear in expenditure are almost exclusively used. In this dissertation, only such specifications will therefore be meant when the label single equation specification is used. One of the most common specifications is when the relationship is assumed to be linear in the logarithms of the variables. It should be noted that if these single equation specifications are to be in accordance with economic theory, the demand must be independent of the level of income, i.e., homothetic (Deaton and Muellbauer, 1980, ch. 3).[1] This restriction follows from the Klein-Rubin theorem and violates Engel's law.[2]

In the system approach one also utilises the fact that the consumer theory indicates that the demands for different products, and in particular close substitutes, are interrelated. This interrelationship follows because the substitution matrix is symmetric and because the budget constraint implies that when the demand for one product increases for a given expenditure, the demand for at least one other product must decrease. Estimating a system allows both a test of the restrictions implied by consumer theory and, when these restrictions are imposed, the parameter estimates are more efficient. Hence, a system approach will provide more information than a single equation approach as the interaction between the demand for different products can be accounted for, and a system approach will provide more efficient parameter estimates.

Studies using single equation specifications together with the work of Pollak (1970), Pollak and Wales (1969; 1992) and Anderson and Blundell (1982; 1983; 1984) on

---

[1] In a complete demand system, the expenditure elasticity must be unity for all the goods in the system. In an incomplete system, the assumption necessary for theoretical consistency is slightly less restrictive, as the expenditure elasticities must either be equal for all goods, or unity for one group of goods and zero for the remaining (LaFrance, 1986).

[2] For a discussion of the Klein-Rubin theorem and restrictions on other functional forms if they are to be theoretically consistent, see Pollak and Wales (1992).

demand systems, indicate that dynamics might be important when considering demand equations.[3] There are several arguments for including dynamics in demand equations, both of economic and statistical origin. The economic arguments are mostly based on the observation that adjustment costs can delay the correction of disequilibrium movements. These adjustment costs may occur under different circumstances such as habit formation, imperfect information and contractual obligations (see e.g. Houthakker and Taylor, 1966; Pollak, 1970). The statistical arguments follow from the strong dependencies over time that time series data tend to exhibit, often leading to invalid inference in static models as the hypothesis of no autocorrelation cannot be rejected. It must be noted that dynamic effects are more likely to be of importance when using aggregated data, than with micro data.

A particularly interesting empirical result is due to Anderson and Blundell (1982; 1983; 1984), who find that with a proper dynamic specification, the symmetry and homogeneity restrictions implied by consumer theory are not rejected. This is in contrast to the results usually obtained in studies using static demand system specifications, where these restrictions are often rejected. See Deaton and Muellbauer (1980, ch. 3) or Deaton (1986) for a discussion of this issue. It should be noted that in most studies using a static specification, the homogeneity and symmetry restrictions are imposed without any testing.

[3] Pollak and Wales (1992) summarise work on demand system specification, in particular, the authors' own work during the period 1969-1992. Their work from this period will therefore not be cited explicitly as general references on this topic.

A problem with the general dynamic specification of Anderson and Blundell in applied work is the difficulty introduced by the system's nonlinear specification. An important objective for this work is therefore to attempt to derive a dynamic system specification which is simpler to use, without losing the generality of Anderson and Blundell's specification.

A problem with the functional forms most commonly used in demand system specification is that the parameters containing most information about the dynamic adjustment process are not identified. Accordingly, these functional forms are not well suited for a study with emphasis on the adjustment process. Another problem with dynamic systems is that they are data intensive, and additional lags quickly deplete the available degrees of freedom, a problem that Hendry (1995, p. 313) dubs "the curse of dimensionality." This problem restricts the size of the system that might be studied with data sets of conventional length, and there is a trade-off between the number of goods included in the system and the number of lags which can be specified. Hence, when one is particularly interested in the dynamic adjustment of demand and not necessarily the demand structure, a single equation specification, which is less complex and data intensive, may be preferable.

An issue which has strongly affected the econometrics in single equation specifications, but which has not had any impact on demand system specifications, is the problem nonstationary data series may cause. This may be a serious issue, since regression on nonstationary data series will normally give spurious results because normal inference theory does not apply (Phillips, 1986). An exception exists when the data series are cointegrated, i.e., form a long-run relationship, and the regressors are strongly exogenous (Engle and Granger, 1987; Phillips, 1991). As most economic data series tend to be nonstationary, this issue will be addressed in this work. In particular, it will be of interest under which conditions normal inference theory may be valid when estimating demand equations with nonstationary data series.

Dynamic specifications of demand equations will be used to study the demand for salmon in the European Union. The demand structure faced by Norwegian salmon farmers will be of particular interest. During the last decade there have been a number of studies on the demand for salmon, or subgroups such as fresh salmon, using time series data (DeVoretz, 1982; Kabir and Ridler, 1984; Bird, 1986; Herrmann and Lin, 1988; Bjørndal, Salvanes and Andreassen, 1992; Bjørndal, Gordon and Salvanes, 1992; Herrmann, Mittelhammer and Lin, 1992; 1993; Bjørndal, Gordon and Singh, 1993; DeVoretz and Salvanes, 1993; Wessells and Wilen, 1993; 1994; Bjørndal, Gordon and Salvanes, 1994). With the exception of Wessells and Wilen (1993; 1994), a common feature of all these studies is the use of a single equation specification for the demand function. Cross-equation interactions between demand functions such as symmetry have been ignored together with most dynamic characteristics. Also, as noted above, single equation demand functions will be in accordance with economic theory only under restrictive assumptions (Deaton and Muellbauer, 1980, ch. 3), e.g. the adding up restriction will hold only if demand is independent of the level of expenditure. A system approach to demand analysis allows the homogeneity and symmetry restrictions implied by economic theory to be tested for or imposed, and the adding up condition to be imposed. Hence, one can ensure that the estimated demand system is in accordance with economic theory. Another advantage is that a system approach leads to more efficient parameter estimation, as more information is utilised when there are cross-equation restrictions and the errors across equations are correlated.

As indicated above, a dynamic specification may be necessary in order to obtain valid inference when using time series data, and also to obtain specifications in accordance with economic theory. Several of these points are likely to be of importance in this study. Dependencies over time in the data series are likely as in all time series. Also, the market for salmon in the European Union has been quite volatile during the last 10-15 years, with a strong increase in the demanded quantities and a substantial decline in the prices (see Tables 3.5, 3.6 and 3.7). Hence, the demand for salmon in the European Union is likely to have departed from an equilibrium, at least periodically. The increased supply of all product forms of salmon and price decline in the late 1980s also indicate that the data series might be nonstationary, and that time series properties should be investigated.

By specifying dynamic systems of demand functions in accordance with consumer theory and by paying attention to the time series properties of the data, it is hoped that the results obtained are more precise than in the earlier studies. The data set used is collected by Eurostat and contains import values and quantities for the product forms fresh, frozen and smoked salmon to the European Union for the period 1981-1992.[4] Demand equations will be specified for fresh, frozen and smoked salmon. This will

[4] Eurostat is the statistical agency of the European Union.

provide more information than in earlier studies, which mostly use either fresh or a total salmon aggregate as a dependent variable and sometimes frozen salmon as one of the regressors.[5] These studies provide little information about the demand for frozen salmon and no information about the demand for smoked salmon and the relation between these goods.

The dissertation is organised as follows. In Chapter 2, issues related to demand specification and estimation will be reviewed. This includes the restrictions consumer theory implies for demand functions if they are to be theoretically consistent. Common empirical specifications of demand functions, both single equation and system approaches, will also be discussed, as will estimation issues such as simultaneity and derived demand. In Chapter 3, the salmon market will be discussed with particular emphasis on the European Union. The data sets will also be presented. In Chapters 4 and 5, different approaches will be taken to analyse the demand for salmon in the European Union. In Chapter 4, the Fully Modified Least Squares (FMLS) estimator of Phillips and Hansen (1990) that incorporates dynamics semi-parameterically, will be used to estimate a demand system containing fresh, frozen and smoked salmon for the European Union. In Chapter 5, the same demand system will be estimated, but the Bewley transformation (Wickens and Breusch, 1988) will be used to give the dynamics a parametric representation. In Chapter 6, issues concerning inference in demand equations when using nonstationary data series will be addressed. In Chapter 7, the attention will be focused on the dynamic adjustment of demand for

[5] An exception is Kabir and Ridler (1984), who also estimate the demand for frozen salmon, although only for Canadian wild-caught Atlantic salmon. Wessells and Wilen (1993; 1994) estimate a demand system containing two categories of salmon, fresh and salted, together with other types of seafood in Japan.

the three product categories of salmon. In Chapter 8, a summary will be presented where the different dynamic specifications and the empirical results will be compared and policy implications discussed.

REFERENCES

Anderson, G. J. and R. W. Blundell (1982) "Estimation and Hypothesis Testing in Dynamic Singular Equation Systems," *Econometrica,* 50, 1559-1571.

Anderson, G. J. and R. W. Blundell (1983) "Testing Restrictions in a Flexible Demand System: An Application to Consumers' Expenditure in Canada," *Review of Economic Studies,* 50, 397-410.

Anderson, G. J. and R. W. Blundell (1984) "Consumer Non-Durables in the U.K.: A Dynamic Demand System," *Economic Journal,* 94, 35-44.

Bird, P. (1986) "Econometric Estimation of World Salmon Demand," *Marine Resource Economics,* 3, 169-182.

Bjørndal, T., D. V. Gordon, and K. G. Salvanes (1992) "Markets for Salmon in Spain and Italy," *Marine Policy,* 16, 338-344.

Bjørndal, T., D. V. Gordon, and K. G. Salvanes (1994) "Elasticity Estimates of Farmed Salmon Demand in Spain and Italy," *Empirical Economics,* 4, 419-428.

Bjørndal, T., D. V. Gordon, and B. Singh (1993) "A Dominant Firm Model of Price Determination in the US Fresh Salmon Market: 1985-1988," *Applied Economics,* 25, 743-750.

Bjørndal, T., K. G. Salvanes, and J. H. Andreassen (1992) "The Demand for Salmon in France: the Effects of Marketing and Structural Change," *Applied Economics,* 24, 1027-1034.

Deaton, A. (1986) "Demand Analysis," In *Handbook of Econometrics*, ed. Z. Griliches and M. D. Intriligator. 1767-1839. Amsterdam: North-Holland.

Deaton, A. S. and J. Muellbauer (1980) *Economics and Consumer Behavior*, New York: Cambridge University Press.

DeVoretz, D. (1982) "An Econometric Demand Model for Canadian Salmon," *Canadian Journal of Agricultural Economics,* 30, 49-60.

DeVoretz, D. J. and K. G. Salvanes (1993) "Market Structure for Farmed Salmon," *American Journal of Agricultural Economics,* 75, 227-233.

Engle, R. F. and C. W. J. Granger (1987) "Co-integration and Error Correction: Representation, Estimation and Testing," *Econometrica,* 55(2), 251-276.

Hendry, D. F. (1995) *Dynamic Econometrics*, Oxford: Oxford University Press.

Herrmann, M., R. C. Mittelhammer, and B. H. Lin (1992) "Applying Almon-Type Polynomials in Modelling Seasonality of the Japanese Demand for Salmon," *Marine Resource Economics,* 7, 3-13.

Herrmann, M. L. and B. H. Lin (1988) "The Demand and Supply of Norwegian Atlantic Salmon in the United States and the European Community," *Canadian Journal of Agricultural Economics,* 38, 459-471.

Herrmann, M. L., R. C. Mittelhammer, and B. H. Lin (1993) "Import Demand for Norwegian Farmed Atlantic Salmon and Wild Pacific Salmon in North America, Japan and the EC," *Canadian Journal of Agricultural Economics,* 41, 111-125.

Houthakker, H. S. and L. D. Taylor (1966) *Consumer Demand in the United States: Analysis and Projections*, Cambridge, MA: Harvard University Press.

Kabir, M. and N. B. Ridler (1984) "The Demand for Atlantic Salmon in Canada," *Canadian Journal of Agricultural Economics,* 32, 560-568.

LaFrance, J. T. (1986), "The Structure of Constant Elasticity Demand Models," *American Journal of Agricultural Economics*, 68, 543-552.

Phillips, P. C. B. (1986) "Understanding Spurious Regressions in Econometrics," *Journal of Econometrics,* 33, 311-340.

Phillips, P. C. B. (1991) "Optimal Inference in Cointegrated Systems," *Econometrica,* 59, 283-306.

Phillips, P. C. B. and B. E. Hansen (1990) "Statistical Inference in Instrumental Variables Regressions with I(1) Processes," *Review of Economic Studies,* 57, 99-125.

Pollak, R. A. (1970) "Habit Formation and Dynamic Demand Functions," *Journal of Political Economy,* 78, 745-763.

Pollak, R. A. and T. J. Wales (1969) "Estimation of the Linear Expenditure System," *Econometrica,* 37, 611-628.

Pollak, R. A. and T. J. Wales (1992) *Demand System Specification and Estimation,* Oxford: Oxford University Press.

Wessells, C. R. and J. E. Wilen (1993) "Economic Analysis of Japanese Household Demand for Salmon," *Journal of the World Aquaculture Society,* 24, 361-378.

Wessells, C. R. and J. E. Wilen (1994) "Seasonal Patterns and Regional Preferences in Japanese Household Demand for Seafood," *Canadian Journal of Agricultural Economics,* 42, 87-103.

Wickens, M. R. and T. S. Breusch (1988) "Dynamic Specification, the Long-Run and the Estimation of Transformed Regression Models," *Economic Journal,* 98, 189-205.

2: DEMAND FUNCTION SPECIFICATION AND ESTIMATION

2.1 Introduction

In this chapter, several issues related to specification and estimation of demand functions will be reviewed. The reviews are only meant to give a brief overview highlighting points relevant to this dissertation. More complete reviews on most of the subjects may be found in several places. There is a well-developed literature on the relationship between consumer theory and demand functions, and on empirical specification of demand functions. Deaton and Muellbauer (1980b) provide excellent reviews of both the consumer theory's implications on demand and empirical specifications. Other works on the same subjects, with somewhat different focuses, are Barten and Böhm (1982), Deaton (1986), Blundell (1988), Pollak and Wales (1992) and Barten (1993). Pollak and Wales (1992) also gives a thorough treatment of functional forms used in analyses of demand systems.

In addition, issues such as dynamic specification, simultaneity and derived demand will be reviewed here. These points are not treated to any extent in the sources cited above. We will discuss the most dynamic specifications used in the literature such as the error correction models of Davidson *et al.* (1978) and relate them to the more common demand specifications that are nested in this general framework. The error correction specification is also used in a demand system specification by Anderson and Blundell (1983; 1984). The simultaneity issues in connection to demand estimation are excellently reviewed by Thurman (1985; 1986; 1987), and the discussion here heavily depends on his work. The relationship between derived demand and consumer demand has been discussed in agricultural economics journals, and Gardner (1975) will be the main source for the discussion here.

This chapter is organised as follows. In Section 2.2, the conditions on a demand system implied by the consumer theory will be reviewed. Of particular interest is what conditions make a demand equation theoretically consistent. In Section 2.3, the concept of weak separability is discussed. This concept is important as it is used a great deal to simplify empirical analysis and data requirements. In Section 2.4, single equation specifications used in the literature are reviewed, for both static and dynamic models. In Section 2.5, several common functional forms for demand system specification are presented and discussed. This includes both the linear expenditure system (LES) and flexible functional forms such as the Rotterdam system, the translog and the almost ideal demand system (AIDS). In Section 2.6, a brief comment on specification of dynamic demand systems is offered, although this issue is treated more extensively later in this dissertation. In Section 2.7, econometric issues in connection to simultaneous equation bias in the estimation of demand equations are discussed. The relationship between consumer demand and derived demand is discussed in Section 2.8. Some comments on demand system specification are given in Section 2.9.

2.2 Theoretical Consistency

I will now briefly review the conditions on consumer demand implied by the consumer theory, i.e., the conditions that make demand functions theoretically consistent. The review is mostly based on Deaton and Muellbauer (1980b) and Cornes (1992).

There are four different representations of the consumer's preferences that are dual in the sense that they provide identical information about the consumer's preferences. These four representations are the utility function, the indirect utility function, the cost (or expenditure) function and the distance function. This gives rise to four different forms of demand functions; direct and inverse, compensated and uncompensated. There is a close relationship between the different approaches. In fact, if we know one representation, we will be able to derive all the others (Diewert, 1971; 1982; Deaton and Muellbauer, 1980b, Ch. 2). This is the core of duality theory, as shown by Diewert (1971).

Most textbook approaches start by reviewing the utility function as a representation of consumer preferences, and this will also be done here. We will assume the consumer's preferences may be represented with a quasi-concave, twice differentiable utility function $U(q)$, where q denotes a vector containing the quantity consumed of each good. The conditions that the consumer's preferences must obey to be represented by this utility function will not be discussed here, but may be found in Deaton and Muellbauer (1980b, ch. 2.1) or Cornes (1992, ch. 2.1).

Let $q=(q_1,\ldots,q_n)>0$ be a bundle of goods with a corresponding vector of prices $p=(p_1,\ldots,p_n)>0$.[1] With utility u from the consumption of the vector q given by a strictly quasi-concave, twice differentiable utility function $U(q)$ and given a budget, X, the consumer's problem is to maximise $U(q)$ given X or

$$(2.1) \quad \max_q \{U(q) | p'q = X\}.$$

The budget X, denotes the consumer's expenditure on the bundle q at prices p. The constraint in (2.1) is therefore also known as the budget constraint.[2] Equation (2.1) gives the following first order conditions:

$$(2.2) \quad \begin{aligned} &\frac{\partial U}{\partial q_i} - \lambda p_i = 0 \\ &p'q - X = 0 \end{aligned}$$

where λ is a Lagrange multiplier. These first order conditions can be solved to yield a system of demand functions, where the demanded quantity for each good is a function of prices and expenditure;

$$(2.3) \quad q_i = g_i(p, X), \text{ for } i=1,\ldots n.$$

These demand functions are known as the uncompensated or Marshallian demand functions, and are homogenous of degree zero in prices and expenditure. This homogeneity property implies that the consumer only considers real prices, as a doubling of all prices and the budget leaves the demanded quantities unaltered. In addition, the budget constraint must hold for the system of demand functions. That the budget constraint is met is known as the adding up condition.

---

[1] Note that the requirement that all prices are positive excludes public goods, and the requirement that all quantities are positive excludes household production.

[2] The budget constraint is often represented with an inequality such that the expenditure must be less or equal to the budget. However, in optimum the equality must hold (Cornes, 1992).

However, there are a few problems with this approach. First, the utility function is a function of exogenous quantities, and by solving the first order conditions for quantities, the original problem is inverted. This problem is easily solved by inverting the utility function obtaining the indirect utility function as the object function, as will be shown below. Moreover, the Marshallian demand functions do not allow us to separate the effects of price and expenditure changes, thereby not allowing us to say anything about the direction of price responses. An alternative way to describe the consumer's optimisation problem which allows us to separate the effects of price and expenditure changes, is to minimise the expenditure of attaining a particular utility level, obtaining the compensated demand functions. This approach will also be reviewed below.

The indirect utility function is obtained by inverting the utility function, or by noting that the demanded quantities (the Marshallian demand functions) are functions of prices and expenditure such that

(2.4) $\max_q \{u(q) | p'q = X\} = F[x(p,X)] = \psi(p,X).$

The indirect utility function, $\psi(p,X)$, derived from the utility function in (2.1), is strictly quasi-convex in prices, twice differentiable and homogeneous of degree zero in prices and expenditure, i.e., a proportional change in prices and expenditure leaves the utility unaltered. The consumer's problem may then be restated using the indirect utility function;

(2.5) $\min_p \{\psi(p,X) | p'q = X\},$

which gives the first order conditions

$$\frac{\partial \psi}{\partial p_i} - \lambda q_i = 0$$

(2.6)

$$p'q - X = 0$$

These may be solved to yield the Marshallian demand functions:

(2.7) $$g_i(p,X) = \frac{\dfrac{\partial \psi}{\partial p_i}}{\sum_k p_k \dfrac{\partial \psi}{\partial p_k}} = -\frac{\dfrac{\partial \psi}{\partial p_i}}{\dfrac{\partial \psi}{\partial X}}, \text{ for } i=1,\ldots n.$$

This expression is known as Roy's identity.

To be able to separate the effects of price and expenditure changes, it is convenient to introduce the concept of a cost or expenditure function. Let the minimum expenditure or cost of attaining a particular utility level *u* be denoted by the cost function *C(u,p)*. The consumer's problem may then be described as minimising the cost of attaining a particular utility level or

(2.8) $$C(u,p) = X = \min_q \{p'q | U(q) = u\},$$

which gives the first order conditions

$$p_i - \lambda U_i = 0$$

(2.9)

$$U(q) - u = 0$$

The cost function must be homogenous of degree one in prices, increasing in *u*, nondecreasing in *p*, concave in prices, and twice differentiable if it is to be equivalent to the utility function in (2.1) as a representation of the consumer's preferences. That the cost function is homogenous of degree one in prices, implies that a doubling in all prices doubles the cost of attaining the same utility level. That it is increasing in u implies that a higher level of utility is only feasible by increasing expenditure. That it is nondecreasing in p, implies that a price increase can not decrease expenditure. The cost function must also be concave in prices, i.e., expenditure rises no more than linearly following a price increase.

The first order conditions (2.9) may be solved to yield the compensated or Hicksian demand functions, which are functions of prices at any given utility level;

(2.10) $q_i = h_i(p,u)$, for $i=1,...n$.

An easier way to obtain (2.10) is by Shephard's lemma, which is an application of the envelope theorem and may be stated as;

(2.11) $\frac{\partial C(u,p)}{\partial p_i} = q_i = h_i(p,u)$, for $i=1,...n$.

The compensated demand functions give the effects of a price change, provided that the consumer's utility level is held constant. The pure effects of price changes may be summarised by the second derivatives of the cost functions, i.e., the Hessian matrix, S;

(2.12) $$S = \frac{\partial C^2(u,p)}{\partial p_i \partial p_j} = \begin{bmatrix} \frac{\partial h_1}{\partial p_1} & \cdots & \frac{\partial h_1}{\partial p_n} \\ \vdots & & \vdots \\ \frac{\partial h_n}{\partial p_1} & \cdots & \frac{\partial h_n}{\partial p_n} \end{bmatrix} = \begin{bmatrix} s_{11} & \cdots & s_{1n} \\ \vdots & & \vdots \\ s_{n1} & \cdots & s_{nn} \end{bmatrix}.$$

This matrix is also known as the substitution matrix or the Slutsky matrix. The concavity of the cost function implies that the Slutsky matrix is negative semidefinite and symmetric. The semidefiniteness follows from the homogeneity restriction and symmetry follows from Young's theorem. This is important, as it allows us to describe the compensated demand functions more accurately than the uncompensated demand functions. The negative semidefiniteness of the substitution matrix implies that the own-price effects are negative, i.e., the compensated demand curves are downward sloping, and Young's theorem implies that cross-price effects are symmetric. In addition, the adding up condition (the budget constraint) must hold, and homogeneity of degree one for the cost function implies that the compensated demand functions are homogenous of degree zero in prices.

The substitution matrix also plays an important part when relating changes in compensated demand to changes in uncompensated demand. When the consumer is at an optimum, compensated and uncompensated demand must be equal, $h(p,u)=g(p,X)$. Differentiating this expression with respect to p holding u constant gives the Slutsky equation. Letting s_{ij} denote the ijth term in the substitution matrix and g_i the uncompensated demand function for the ith good, the Slutsky equation may be written as:

$$(2.13)\quad s_{ij} = \frac{\partial g_i}{\partial p_j} + q_j \frac{\partial g_i}{\partial X}$$

The compensated effect of a change in the price of good j on the demand for good i can here be seen to be equal to the uncompensated effect plus the "compensation" given as the expenditure derivative, $\partial g_i / \partial X$, times the consumption of good j. Commodity j is said to be a net or Hicksian substitute (complement) for commodity i if $s_{ij}>0$ (<0) and a gross or Marshallian substitute (complement) if $\partial g_i / \partial p_j>0$ (<0). If the income effect $\partial g_i / \partial X$ is positive, good i is said to be normal, and if the income effect is negative, good i is said to be inferior. Note that the Marshallian own-price effect does not have to be negative. If the income effect is large enough and negative, the absolute value of the compensation may be larger than the absolute value of the Hicks substitution effect and give a positive Marshallian own-price effect. Such goods are know as Giffen goods, and are unlikely to occur in applied work.[3]

As noted above, solving the first order conditions from the utility function (2.2) for the exogenous variable q, is a little bit peculiar. A more conventional approach would be to solve for price, yielding the uncompensated inverse demand functions (Anderson, 1980):

(2.14) $$p_i = f_i(q, X) = \frac{\frac{\partial U}{\partial q_i}}{\sum_k q_k \frac{\partial U}{\partial q_k}} X \text{, for } i=1,...n.$$

Another common representation of the uncompensated inverse demand functions is to express the functions in normalised or real prices;

(2.15) $$\frac{p_i}{X} = f_i(q) \text{, for } i=1,...n.$$

The uncompensated inverse demand functions are homogenous of degree one in X, i.e., a doubling of the budget will double all prices, and homogenous of degree zero in q. However, as with the uncompensated demand functions, we can say little about the shape of the uncompensated inverse demand functions, as it is not possible to separate the quantity and scale effects. A scale effect is the derivative of f with respect to the distance measure d (Anderson, 1980). An interpretation of d is given in the next paragraph.

[3] However, examples where a good is reported to be a Giffen good do exist. See Johnston and Larson (1994) for a discussion of when Giffen goods may exist, and references to empirical studies where Giffen goods are reported. It should be noted that in most cases when Giffen goods are reported, even the authors note that econometric misspecification is a likely problem.

To separate the quantity and scale effects, a function with properties quite similar to the cost function, the distance function, is introduced. The distance function is defined as

$$(2.16)\quad D(q,u) = \max_d \{d | U(q/d) = u\}.$$

The distance function minimises the distance between a reference bundle q^*, and a multiple, $(1/d)$, of this bundle necessary to reach the utility level u. It is decreasing in u, homogenous of degree one in q, and concave in q. It may also be expressed in relation to the cost function as

$$(2.17)\quad D(q,u) = \min_p \{p'q | C(u,p) = X\}.$$

Solving the first order conditions from either (2.16) or (2.17) will give rise to the compensated inverse demand functions, $a(q,u)$. These may also be obtained by an inverse form of Shephard's lemma as (Deaton and Muellbauer, 1980b, p. 56);

$$(2.18)\quad \frac{\partial D(q,u)}{\partial q_i} = \frac{p_i}{X} = a_i(q,u)\text{, for } i=1,\ldots n.$$

As the distance function is concave in q, its Hessian will take the same form as the substitution matrix from the cost function. This matrix gives the pure effect of a quantity change on prices, and is known as the Antonelli matrix, A;

$$(2.19)\quad A = \frac{\partial D^2(q,u)}{\partial q_i \partial q_j} = \begin{bmatrix} \frac{\partial a_1}{\partial q_1} & \cdots & \frac{\partial a_1}{\partial q_n} \\ \vdots & & \vdots \\ \frac{\partial a_n}{\partial q_1} & \cdots & \frac{\partial a_n}{\partial q_n} \end{bmatrix} = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix}.$$

As the distance function is concave in q, the Antonelli matrix is negative semidefinite, the compensated inverse demand functions are downward sloping and the cross-equation effects are symmetric.

The Antonelli matrix plays the same role in relating changes in uncompensated inverse demand functions to compensated inverse demand functions as the substitution matrix does for direct demand functions. This gives a relationship similar to the Slutsky equation (Anderson, 1980), and may be written as;

$$(2.20) \quad a_{ij} = \frac{\partial f_i}{\partial q_i} + p_j \frac{\partial f_i}{\partial d}.$$

The compensated effect of a change in the quantity of good j on the inverse demand for good i is equal to the uncompensated effect plus the scale effect. Depending on the sign of a_{ij}, the compensated inverse demand functions give rise to the notion of q-substitutes ($a_{ij}<0$) and q-complements ($a_{ij}>0$).[4] To the author's knowledge, a similar notation does not exist for the uncompensated inverse demand effects. However, the terminology of gross and net substitutes (complements) may of course also be used with inverse demand relationships.

There is an intimate relationship between the Antonelli and the Slutsky matrices, although two goods which are direct substitutes do not need to be q-substitutes and vice versa. Letting S denote the Slutsky matrix, A the Antonelli matrix and X expenditure, the two matrices are related by the following symmetric relationships (Deaton and Muellbauer, 1980b, p. 57);

[4] Using the same terminology, the direct compensated effects can be denoted as p-substitutes and p-complements.

(2.21) $S = XSAS,\ A = XASA$.

That is, the Slutsky and Antonelli matrices are generalised inverses of each other.

With all these equivalent representations of consumer demand, an interesting question is, which one to use? The answer is, it depends. In most cases, each consumer's demand is assumed to be so small that it will not affect the market price, i.e., each consumer is a price taker. This will be the case in a free market with many consumers, each demanding only a small fraction of the total for each good. In such cases, direct demand functions are an obvious candidate as the prices are treated as exogenously given. Whether we choose a compensated or an uncompensated system depends on what information we want, although knowledge of one also enables us to derive the other. Inverse demand functions are not commonly used in consumer analysis, as the consumers mostly are assumed to be price takers. However, they are the most suitable representation when quantities are rationed or a market for the goods in question does not exist. Also, even if direct and inverse demand systems give equivalent descriptions of the consumer's preferences, there are econometric reasons for considering both. In particular, in situations with a downward-sloping demand curve and an upward sloping supply curve, observations of a commodity's price and quantity are not sufficient to identify the demand and supply curves. This problem will be considered in more detail in Section 2.7.

2.3 Weak Separability

An unattractive feature of the just described general approach for empirical purposes is that the demand for any commodity is a function of the price of all other commodities demanded by the consumer. However, this problem may be circumvented with the notion of weak separability of the consumer's preferences (Deaton and Muellbauer, 1980b, Ch. 5; Deaton, 1986; Barten, 1993). The reasoning behind this concept is that the optimisation problem is also untractable for the consumer if the demand for every commodity is a function of the prices of all other commodities. To simplify this problem, we may assume that the consumer partitions total consumption into groups of goods, so that preferences within groups can be described independently of the other groups. For instance, the consumer may divide total consumption into groups such as housing, clothing, leisure and food. Each of these groups may also be divided into finer groups, e.g. food may be divided into fruits, vegetables, meats, fish and other. A price change in one good will then affect only other goods in the same group directly, commodities in any other group will only be affected through the change in total expenditure as the price change makes the consumer richer or poorer.

More formally, under weak separability the consumer maximises utility, $u = U(U_1(q^1),...,U_p(q^p))$, from the p different groups of commodities, where each vector $q^i = (q_1^i,...,q_r^i)$ may consist of one or more goods and no good belongs to more than one group. Each function $U_i(\cdot)$ is a proper utility function given the budget allocated to group *i*, and is known as the subutility function or the felicity function for group *i*.

The notion of weak separability is closely related to two-stage budgeting. Under two-stage budgeting, the consumer first allocates the budget over broader groups such as housing, clothing, leisure and food, while at a second stage group expenditures are allocated to individual commodities. At each stage, information appropriate to that stage only is required, and the allocation at both stages must be perfect in the sense that the results of two-stage budgeting must be identical to what would occur if the allocation were made in one step with an ordinary utility function. Weak separability and two-stage budgeting do not imply each other, but weak separability is both necessary and sufficient for the second stage of two-stage budgeting (Deaton and Muellbauer, 1980b, p. 124). In particular, weak separability does not give any rules for how expenditure is allocated outside each group.

The notion of weak separability is extremely important for empirical work, as it gives a rationale for singling out and studying only a small group of closely related goods. Later, we will see that weak separability is necessary to specify systems of demand functions consistent with the consumer theory in applied work. However, it should be noted that weak separability between the goods studied and the rest of a consumer's bundle is generally assumed before the empirical specification, and not tested as a hypothesis. Even if this assumption may seem reasonable, there is little or no evidence that it is correct. It is possible to test for weak separability (Eales and Unnevehr, 1988; Salvanes and DeVoretz, 1993), but it is hard to find data sets of sufficient size and richness that will allow this, and it also involves serious aggregation issues.

2.4 Single Equation Specifications

The first empirical demand studies were mostly concerned with estimating elasticities and paid little attention to the consumer theory (Deaton and Muellbauer, 1980b, p. 61). By not paying attention to theory, theoretical properties of demand, such as adding up and symmetry, are ignored. The researchers specified (mostly quantity dependent) single equation demand functions linear in the parameters, of which the double log was the most common specification (Deaton and Muellbauer, 1980b, p. 17).[5] This specification is still common today. Letting q_{it} be the quantity consumed of good i at time t, p_{jt} the price of good j at time t and X_t the expenditure at time t, the equation to be estimated with this specification is

$$(4.1) \quad \ln q_{it} = \alpha_i + \sum_j e_{ij} \ln p_{jt} + e_i \ln X_t$$

The advantage with this specification is that the estimated parameters can be interpreted as elasticities as $e_{ij} = \partial \ln q_{it} / \partial \ln p_{jt}$ (the cross price elasticity) and $e_i = \partial \ln q_{it} / \partial \ln X_t$ (the expenditure elasticity). The range of j varies, and typically includes commodities which are assumed to be closely associated with good i. The measure of expenditure X_t is typically a (often highly aggregated) measure of the consumer's income. Early examples of this specification may be found in Stone (1954a) and Prais and Houthakker (1955).[6]

[5] As noted in Chapter 1, when discussing single equation specifications, only specifications that are linear in expenditure are considered.

[6] It should be noted that parts of Stone's analyses are a bit different from most studies in this tradition in that he uses economic theory to derive compensated demand functions, instead of the uncompensated demand functions which normally are estimated. This makes the potential problems with the adding up conditions less serious.

Economists had early discovered that dynamics might be important in the consumer's behaviour (Duesenberry, 1949; Stone 1954a). The first explicit attempt to specify demand functions that distinguished between short- and long-run behaviour was, to the author's knowledge, Houthakker and Taylor's (1966) habit formation model.[7] This model is based on the double log and may be written as

$$(4.2) \quad \ln q_{it} = \alpha_i + c_i \ln q_{it-1} + \sum_j e_{ij} \ln p_{jt} + e_i \ln X_t .$$

The dynamics are introduced in the lagged consumption variable, q_{it-1}, which makes current consumption dependent on the previous period's consumption. The short-run elasticities are e_{ij} and e_i, and the long-run elasticities are found by setting $\ln q_i$ equal at all times, as implied by the notion of long-run equilibrium. The long run elasticities may then be computed from (4.2) as $\eta_{ij} = e_{ij}(1-c_i)^{-1}$ and $\eta_i = e_i(1-c_i)^{-1}$. To be consistent with utility maximisation, the parameter c_i must be between zero and one. This seems to hold in all empirical analyses.

During the 1970s, very dynamic models, mostly motivated by problems with persistent autocorrelation and bad forecasting abilities, appeared in the macro economic literature, particularly in connection with the consumption function. The work of Davidson *et al.* (1978) has left a major impact, not only on macroeconomic work, but on all empirical work in economics based on time series data, including demand analysis. An excellent discussion of their approach may be found in Banerjee *et al.* (1993). The basic formulation is an autoregressive distributed lag model based

[7] Houthakker and Taylor (1966) are often cited for their extended second edition from 1970. The first edition is preferred here because it is important for the work of Pollak and Wales (1969) and Pollak (1970) which will be commented on later.

on some functional form, usually a functional form linear in the logarithms of the variables.[8] Based on a double log, this may be written as

$$(4.3)\quad \ln q_{it} = \alpha_i + \sum_{k=1}^{r} c_{ik} \ln q_{it-k} + \sum_{j} \sum_{l=0}^{s} e_{ijl} \ln p_{jt-l} + \sum_{l=0}^{s} e_{il} \ln X_{t-l}.$$

The numbers of lags, r and s, is an empirical question. They are chosen large enough to account for all dynamics such that the resulting residual in the empirical specification is white noise.

There are both statistical and economic arguments for including lags in a model such as (4.3). The statistical arguments are founded on the observation that often in time series data there exist dependencies in the data over time. To capture these dependencies, dynamic specifications are necessary. The economic arguments are all arguments against the hypothesis of instantaneous adjustment to changes in economic variables. As instantaneous adjustment implies a static model, the arguments against instantaneous adjustment are also arguments against a static model. The hypothesis of habit formation discussed above is a dynamic model. However, other limitations on the adjustment process such as contractual obligations and imperfect information, which induce adjustment costs can also invalidate the hypothesis of instantaneous adjustment. These restrictions require more general dynamic specifications than the habit formation model. To model demand when these features are present, a general dynamic model is necessary. The advantage with (4.3) is that all linear dynamic structures are included as special cases (Anderson and Blundell, 1982).[9]

---

[8] The presentation here differs from Davidson *et al.* (1978), as they use a four period filter motivated by their quarterly data. This is a special case of the model presented here.

[9] It must be noted that autocorrelation may be introduced in a model when an incorrect functional form is used (Alston and Chalfant, 1991).

Note that the habit formation model in (4.2) is a special case of (4.3) with r=1 and s=0. Each parameter in (4.3) gives the elasticity of one variable at a particular lag with respect to current consumption. The long-run elasticities are found by summing over all the lags. Hence, the long-run elasticities from (4.3) are $\eta_{ij} = \sum_l e_{ijl}(1-\sum_k c_{ik})^{-1}$ and $\eta_i = \sum_l e_{il}(1-\sum_k c_{ik})^{-1}$. An inconvenience with this model is that the long-run elasticities which are of greatest interest, must be computed after estimation. The model in (4.3) was therefore transformed into the following model by Davidson *et al.* (1978);

$$\begin{aligned}\Delta \ln q_{it} &= \alpha_i + \sum_{k=1}^{r-1} C_{ik} \Delta \ln q_{it-k} + \sum_j \sum_{l=0}^{s-1} E_{ijl} \ln p_{jt-l} + \sum_{l=0}^{s-1} E_{il} \ln X_{t-l} \\ &\quad - \omega(\ln q_{t-r} - \sum_j \eta_{ij} \ln p_{jt-s} - \eta_i \ln X_{t-s})\end{aligned} \quad (4.4)$$

The relationships between the parameters in (4.3) and (4.4) are

$$C_k = \sum_{k=1}^{K} c_{ik} - 1,\ \ E_{ijl} = \sum_{l=0}^{L} e_{ijl},\ \ E_{il} = \sum_{l=0}^{L} e_{il},\ \ \omega = 1 - \sum_{k=1}^{r} c_{ik}\ .$$

Specifications such as (4.4) are known as error correction models (ECM). The advantage of such models are that the long-run parameters (elasticities) are directly estimated. The parameter ω is also of interest as it may be interpreted as the adjustment speed towards equilibrium. An inconvenience with this specification is that it is nonlinear, requiring use of the more computationally difficult nonlinear estimation techniques. However, this may be circumvented in several ways, as described by Wickens and Breusch (1988) or Bårdsen (1989). Specifications based on (4.4) have also been common in demand analyses during the last decade, see e.g. Bird (1986), Johnson *et al.* (1992) and Salvanes *et al.* (1994).

Other single equation specifications similar to the double log but without or with only some logarithmic variables have also been used in the literature. These are, for instance, specifications where the data series are linear in their levels, see e.g. DeVoretz and Salvanes (1993). More recently, also Box-Cox transformations have been estimated. The advantage with these models is that the functional form decides the right transformation of the variables, and includes the double log and the linear model as limit cases. An empirical example may be found in Bjørndal, Salvanes and Andreassen (1992).

Even if the major body of work on demand function estimation with single equation specifications has used quantity dependent models, there are examples where price is used as the dependent variable. This is especially true in studies of agricultural and fishery commodities (see e.g. Shonkwiler and Taylor, 1984). It must also be noted that the much studied problem of simultaneity in price and quantity mostly has been formulated with single equation demand (and supply) functions (Eales and Unnevehr, 1993). This problem has mostly been ignored in demand system specifications, as demand has been assumed to be completely price or quantity dependent. A more detailed discussion of simultaneity in demand equation estimation is given in Section 2.7.

There exist two major problems with single equation models. In general, they are not theoretically consistent, because the budget restriction (or the adding up condition) in general holds only when demand is independent of expenditure, i.e., the consumer's preferences are homothetic (Deaton and Muellbauer, 1980b, p. 17-18). This follow from the Klein-Rubin theorem (Klein and Rubin, 1947-48).[10] This also violates Engel's law, which claims that the propensity to consume a particular group of goods varies with total expenditure (Deaton and Muellbauer, 1980b, p. 193). It should be noted that it is sometimes argued that in the analysis of a single commodity, where the functional form of the other goods in the system remains unspecified, single equation specifications may produce satisfactory local approximations, in particular if there is not too much variation in total expenditure.

The single equation models specify uncompensated demand equations. The prices of the goods omitted from the specification may then cause problems because any change in either of them causes changes in demand for the commodity in question through changes in expenditure. This problem may be reduced if one specifies a compensated demand function (Stone, 1954a). In empirical work this problem may not be too serious, as the effect is small if the particular good represents a small portion of the budget.

2.5 Demand Systems

In order to estimate demand functions that are consistent with utility maximisation, the concept of weak separability discussed above is used to separate a group of goods from the rest of the consumer's bundle. The demand functions for the goods inside the group are then specified in a system of demand functions where the adding up

[10] It should be noted that in an incomplete demand system, the expenditure elasticity may differ from unity, if they are equal for all goods, or equal to unity for one group of goods and zero for the remaining goods (LaFrance, 1986).

condition is imposed and the homogeneity and symmetry restrictions associated with consumer theory can be tested or imposed. These conditions, together with the trivial assumptions of positive prices and consumption, ensure that the demand system is consistent with consumer theory.[11] Most, but not all systems are derived from an explicitly formulated utility, indirect utility or cost function. However, this is not a necessary condition for theoretical consistency. Also, only demand systems are used in empirical work as it is not possible to measure or compare utility. For a discussion of the connection between the functional form of a utility, indirect utility or cost function and each of the demand systems where this can be explicitly formulated, see Pollak and Wales (1992). We will concentrate on demand systems in the following, where some of the most commonly used demand systems, the linear expenditure system, the Rotterdam system, the translog and the almost ideal demand system, will be presented. The demand systems presented are by no means the only demand system specifications used in the literature, and many other examples are reviewed in Pollak and Wales (1992, Ch. 2). The systems are chosen because they are or have been the most commonly used systems, particularly when using time series data.[12]

2.5.1 The Linear Expenditure System

The linear expenditure system (LES) (Klein and Rubin, 1947-48; Stone, 1954b), or the Stone-Geary system as it is also known, is the simplest of the demand systems, but is not commonly used today. This specification is important as it was the first

[11] It should be noted that positive consumption is not absolutely necessary, and in some studies using cross section data at a micro level, zero consumption is allowed, see e.g. Heien and Wessells (1988; 1990), Wellman (1992) and Salvanes and DeVoretz (1993).

[12] This selection of systems may of course be debated. For instance the quadratic expenditure system which has been extensively used by Pollak and Wales may indeed qualify as a commonly used system.

theoretically consistent demand system to be specified and estimated (Stone, 1954b), and it was important in empirical work into the mid 1970s.

Each equation in the linear expenditure system may be written as

$$(5.1) \quad q_{it} = b_i - \frac{a_i}{p_{it}} \sum p_{jt} b_j + \frac{a_i}{p_{it}} X_t, \quad \sum_i a_i = 1,$$

where X_t denotes the expenditure on the n goods in the system and the a_i's and the b_i's are the parameters to be estimated. The parameters b_i are often interpreted as the minimum or subsistence quantity consumed of each good i, while the parameter a_i is the fixed proportion of expenditure that is allocated to each good when the subsistence expenditure is covered. A more common specification in empirical work is to write each demand equation as a budget share equation. The budget share equations for (5.1) are obtained by multiplying through each equation with p_{it} and $1/X_t$, and may then be expressed as

$$(5.2) \quad w_{it} = \frac{p_{it} b_i}{X_t} + a_i \left[1 - \frac{\sum p_{jt} b_j}{X_t} \right],$$

where w_{it} denotes the budget share for good i. The advantage with this formulation is that the adding up condition is imposed on the data, and it is thereby automatically satisfied. For this reason, also all the demand systems presented below are formulated as budget share equations.

There are several weaknesses in the linear expenditure system that make it unattractive in applied work. As the name indicates, the demand functions are linear in expenditure and accordingly, Engel's law cannot hold. Moreover, it is not possible to test restrictions implied by the consumer theory, such as the hypotheses of symmetry and homogeneity. The functional form is also restrictive in that only substitutes and normal goods are allowed, if the system is to be theoretically consistent.

2.5.2 Flexible Functional Forms

The restrictiveness of the functional form in the linear expenditure system can also be seen by noting that only *2n-1* free parameters are estimated. This corresponds to *n* intercepts and *n-1* expenditure effects in a system with *n* goods, with one free parameter removed because of the adding up restriction. There are no parameters free to measure the price effects (Deaton, 1986). The lack of measurable effects also prevents testing of the restrictions implied by the consumer theory on the demand system. To overcome this problem, more general functional forms, able also to measure the price effects, were introduced. These functional forms are known as flexible functional forms.

Diewert (1974) defines a flexible functional form as a function that is capable of providing a second order approximation to an arbitrary production/utility function. Diewert speaks of the production and utility function. This implies that the demand systems are first order approximations to the underlying true demand system, and that the underlying utility, indirect utility and cost functions are second order approximations to the same true functions.

With adding up imposed by the data, a flexible functional form must have $(2+n)(n-1)$ free parameters. Homogeneity corresponds to $(n-1)$ restrictions and symmetry to $1/2n(n-1)$ restrictions. With these restrictions imposed, the functional form has $1/2(n+1)(n+2)$ separate effects, but it is not a second order approximation anymore in the mathematical sense (Deaton, 1986). However, it is a flexible functional form with respect to the theory.

The following demand systems are flexible functional forms, and are preferred to the linear expenditure system in most applied work because of their flexibility. In addition to the possibility of testing restrictions implied by consumer theory, this flexibility is important as it allows free estimates of the price effects to be obtained.

However, flexibility is not necessarily the most important feature of a functional form (Pollak and Wales, 1992, p. 64). For instance, a Quadratic Expenditure System (QES) (Howe, Pollak and Wales, 1979) will on many occasions have the same number of free parameters as a flexible functional form, even though it is not flexible as it is not able to approximate all the cross price effects. Is the QES then more restrictive than a flexible functional form? According to Pollak and Wales (1992, p. 64) the answer is no. Rather, the QES emphasises other features of demand by providing a more detailed description of own-price and expenditure effects.

How suitable a functional form is depends on both the data available and what questions one wants to ask. Flexible functional forms are most suitable when one want to measure substitution effects, particularly when using time series data, which is most suitable for this purpose. Other functional forms such as the QES may be more suitable when one is primarily interested in own-price and expenditure effects, particularly when using cross section data. As time series data will be used in this dissertation, and the substitution relationships between goods are of interest, flexible functional forms seem best suited.

2.5.3 The Rotterdam System

The Rotterdam system of Theil (1965) and Barten (1966; 1967; 1968) was the first attempt to address some of the limitations of the linear expenditure system. The demand equations are in budget share form and satisfy the adding up condition automatically. The symmetry and homogeneity restrictions implied by consumer theory may be expressed as linear functions of the estimated parameters. Consequently, one may either test if the data are in accordance with the consumer theory for this specification, or impose these restrictions on the estimated parameters to ensure theoretical consistency. Note that this, and most other empirical specifications, is an approximation to the underlying demand equations.[13] The results may in all specifications be dependent on the functional form. In particular, a rejection of the hypothesis of symmetry and homogeneity does not necessarily imply that the consumer theory is false. It might just as well be caused by empirical (mis-) specification, of which choice of functional form is an important part.

[13] It is of course possible to postulate that the consumers' preferences actually correspond to the demand equations from a particular functional form.

Another improvement with the Rotterdam system compared to the linear expenditure system is that it allows for free estimation of price effects, and for complements and inferior goods without losing its theoretical consistency. Each equation in the Rotterdam system may be written as

$$(5.3) \quad w_{it} d\ln q_{it} = b_i d\ln \bar{x}_t + \sum_j c_{ij} d\ln p_{jt},$$

where

$$d\ln \bar{x}_t = d\ln x_t - \sum_j w_{jt} d\ln p_{jt} = \sum_j w_{jt} d\ln q_{jt}$$

$$b_i = w_{it} e_i = p_{it} \frac{\partial q_{it}}{\partial x_t}$$

$$c_{ij} = w_{it} e_{ij}^{\bullet} = \frac{p_{it} p_{jt} s_{ij}}{x_t}$$

Remember that e_i is the expenditure elasticity for good i. We also have that $e_{ij}^{\bullet}$ is the compensated cross-price elasticity, which is related to the uncompensated and expenditure elasticities by Slutsky's equation on elasticity form, $e_{ij} = e_{ij}^{\bullet} - e_i w_j$. The raw form of the Slutsky equation is $s_{ij} = \frac{h_i}{\partial p_j} = \frac{\partial g_i}{\partial p_j} + q_j \frac{\partial g_i}{\partial X}$, where each element s_{ij} corresponds to the ijth element in the substitution matrix (see equation (2.12)). The continuos difference operators d are in applied work replaced by their discrete approximation Δ.

The adding up restrictions imply that

$$(5.4) \quad \sum_i b_i = 1, \; \sum_i c_{ij} = 0.$$

These restrictions are automatically satisfied when the budget shares in the data set add to unity. However this restriction makes the covariance matrix singular. One must therefore delete one equation from the demand system before estimation. With correct estimation technique and an $iid(0,I\otimes\Sigma)$ error term, the system is invariant to which equation is deleted (Barten, 1969), and the adding up restrictions from (5.4) are used to retrieve the parameters in the deleted equation.[14] This is also a feature the Rotterdam system has in common with all the other systems of demand equations formulated in their budget share equations. The symmetry and homogeneity restrictions may be expressed as functions of the parameters in the Rotterdam system. They may be written as:

(5.5)

Symmetry: $c_{ij} = c_{ji}$.

Homogeneity: $\sum_j c_{ij} = 0$.

As mentioned above, the restrictions may be used to test whether the data support a theoretically consistent specification of the Rotterdam system. They may also be imposed to ensure that the estimated system is theoretically consistent.

The Rotterdam system is common in the literature, and there also exists an inverse version (Barten and Bettendorf, 1989). The Rotterdam system differs from most other functional forms in that its utility or cost functions never have been explicitly formulated, and that differential demand functions are used instead of functions formulated in the levels of the variables.[15]

[14] Identically independently distributed errors is a fairly strict assumption. It is used because it makes the statistical arguments easier. However, the arguments hold also under weaker assumptions, see White (1984, ch. 7).

[15] There is some discussion in the literature about the appropriateness of using differential demand functions as in the Rotterdam system. In particular, it is not clear that the differential demand functions

2.5.4 The Translog System

The translog (Christensen *et al.*, 1971; 1973) has been the most common flexible functional form in production analysis since the mid 1970s. A consumer demand system derived from an indirect translog utility function by Roy's identity was first applied by Christensen *et al.* (1975), and this formulation has since been rather common. The share equations are given as

$$(5.6) \quad w_{it} = \frac{\alpha_i + \sum_j \beta_{ij} \ln\left(\frac{p_{jt}}{X_t}\right)}{1 + \sum_i \sum_j \beta_{ij} \ln\left(\frac{p_{jt}}{X_t}\right)}$$

The restrictions associated with this formulation are:

Adding up: $\sum_i \alpha_i = 1, \quad \sum_i \beta_{ij} = 0.$

(5.7) Symmetry: $\beta_{ij} = \beta_{ji}.$

Homogeneity: $\sum_j \beta_{ij} = 0.$

The translog demand system shares some of the features of the Rotterdam system in that the adding up restrictions are automatically imposed and one equation must be deleted before estimation to avoid a singular covariance matrix. The symmetry and homogeneity restrictions may be tested for or imposed. There exists no clear criteria for choosing between the Rotterdam system and the translog system. What functional form will perform best depends on the true structure in the underlying data. An

---

will correspond to the underlying demand functions in levels under all circumstances (Phlips, 1974; Deaton, 1986).

argument against the translog system in applied work is the fact that nonlinear estimation routines are necessary in order to estimate the system.

2.5.5 The Almost Ideal Demand System

The most common functional form in demand system specification since the early 1980s has been the almost ideal demand system (AIDS) of Deaton and Muellbauer (1980a). As with the Rotterdam and translog systems, the almost ideal demand system is formulated in terms of the budget shares, and each demand equation can be written as

$$(5.8)\quad w_{it} = \alpha_i + \sum_j \gamma_{ij} \ln p_{jt} + \beta_i \ln\left(\frac{X_t}{P_t}\right),$$

where

$$\ln P_t = \alpha_0 + \sum_i \alpha_i \ln p_{it} + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln p_{it} \ln p_{jt}\ .$$

The almost ideal demand system is linear except for the translog price index $\ln P_t$. This problem has traditionally been circumvented in most applied work as suggested by Deaton and Muellbauer, by using a Stone price index, i.e., $\ln P_t^* = \sum_i w_{it} \ln p_{it}$, which makes the system linear. The Stone index has also been shown to do well compared to the translog index in some empirical work (e.g. Anderson and Blundell, 1983). However, recently the use of the Stone price index has been shown to be inappropriate as it causes the estimated parameters to be inconsistent (Pashardes, 1993; Buse, 1994; Moschini, 1995). Moschini attributes this problem to the fact that the Stone price index does not satisfy what Diewert calls the commensurability property, and suggests that the problem may be solved by using a price index that satisfies this property.[16] Moschini suggests several other price indices which satisfy this property and may be used to keep a linear specification of the almost ideal demand system (see also the discussion in the next section). He also shows that these indices perform as well as the translog index in a Monte Carlo experiment. To keep the specification of the demand system linear, we will use the price index that Moschini calls the "corrected" Stone index, which may be written as

$$(5.9) \qquad \ln P_t^S = \sum_i w_{it} \ln\left(\frac{p_{it}}{p_i^0}\right),$$

where p_i^0 denotes base period (Moschini suggests that the mean is used as the base period). When the almost ideal demand system is referred to later in this dissertation, the linear version is meant if nothing else is noted.

The restrictions to ensure theoretical consistency for the almost ideal demand system are:

Adding up: $\sum_i \alpha_i = 1, \quad \sum_i \gamma_{ij} = 0.$

(5.10) Symmetry: $\gamma_{ij} = \gamma_{ji}.$

Homogeneity: $\sum_j \gamma_{ij} = 0.$

The almost ideal demand system is parallel to the Rotterdam and translog systems in that the adding up restrictions are automatically imposed and one equation must be deleted before estimation to avoid a singular covariance matrix. The symmetry and homogeneity restrictions may be tested or imposed. There exist no clear criteria for

[16] The commensurability property means that a price index should be invariant to the unit of measurement for the prices.

choosing among the almost ideal demand system and the other two systems, and which functional form will perform best depends on the true structure in the underlying data. The almost ideal demand system has the advantage that it is linear and formulated in levels. It may accordingly be encountered as more intuitive and easier to use than the Rotterdam and translog systems. In common with the Rotterdam system, the almost ideal demand system also has an inverse representation (Eales and Unnevehr, 1993).

2.5.5.1 The Relationship Between the Nonlinear and the Linear Approximate Almost Ideal Demand Systems

Recently, there have been a number of papers discussing the relationship between the nonlinear and the linear approximate almost ideal demand systems (Green and Alston, 1990; 1991; Pashardes, 1993; Alston, Foster and Green, 1994, Buse, 1994; Moschini, 1995). These papers mostly focus on two issues; how well does the linear approximate almost ideal demand system approximate the nonlinear system and what are the correct expressions for the elasticities in the linear approximate almost ideal demand system.

First, note that the use of the Stone price index transforms the constant term in (5.8) to $\alpha_i^* = \alpha_i - \beta\alpha_0$. The linear approximate almost ideal demand system can then be written as

$$(5.11)\quad w_{it} = \alpha_i^* + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln\left(X_t / P_t^*\right)$$

As noted above, the Stone price index has recently been shown by several authors to make the parameter estimates inconsistent. Most authors attribute this problem to the fact that it introduces a measurement error because the prices are never perfectly colinear, which they must be for the Stone price index to equal the translog price index in (5.8). However, Moschini (1995) attributes the problem to the fact that the Stone price index is not commensurable, and suggests several alternative price indices that solve this problem. In addition to the "corrected" Stone price index above, which may be regarded as the loglinear analogue to the Paasche index, there are the Tornqvist index

$$(5.12)\quad \ln P_t^T = \frac{1}{2}\sum_{i=1}^{n}\left(w_{it} + w_i^0\right)\ln\left(p_{it} / p_i^0\right)$$

which is a discrete approximation to the Divisia index, and the loglinear analogue to a Laspeyre index, which may be written as

$$(5.13)\quad \ln P_t^L = \sum_{i=1}^{n} w_i^0 \ln\left(p_{it}\right).$$

This index should be comforting if one worries that the presence of w_{it} in the other linear indices on the right-hand side of the equation introduces a simultaneity problem. Moschini (1995) shows in a Monte Carlo experiment that all of these indices perform very well.

Several authors have been concerned about how well the linear version of the almost ideal demand system approximates the nonlinear integrable system. We will show that when prices are normalised to unity, the two representations are equal when evaluated at the point of normalisation.[17,18]

We first look at the nonlinear version. With the price normalised at some point, at this point, (5.8) reduces to

(5.14) $w_{it} = \alpha_i + \beta_i \ln X_t - \beta_i \alpha_0$.

If α_0 is set equal to the logarithm of expenditure in the base period, which is done at the point where the elasticities are evaluated in some empirical studies (Blanciforti, Green and King, 1986; Buse, 1994), α_i equals the predicted budget share at the point of normalisation.

Similarly, at the point of normalisation, each equation in the linear approximate almost ideal demand system (5.11) reduces to

(5.15) $w_{it} = \alpha_i^* + \beta_i \ln X_t = \alpha_i + \beta_i \ln X_t - \beta_i \alpha_0$,

which is identical to (5.14). However, note that when the Stone price index is used, there may be a difference between (5.8) and (5.11) in applied work, as the estimated parameters in the linear approximate almost ideal demand system are inconsistent. This problem is avoided if one of the indices suggested by Moschini (1995) is used.

Next, turn to the computation of the elasticities. The uncompensated elasticity for the nonlinear almost ideal demand system is given as

---

17 In this dissertation, prices are normalised to unity at mean when the almost ideal demand system is used.

18 Note that the Stone index and the "corrected" Stone index are identical if prices are normalised before the index is computed.

$$(5.15)\quad \eta_{ij} = -\delta + \left(\frac{\gamma_{ij}}{w_{it}}\right) - \left(\frac{\beta_i}{w_{it}}\right)\left(\alpha_j + \sum_{j=1}^{n} \gamma_{ij} \ln p_{jt}\right),$$

where δ is the Kronecker delta. At the point of normalisation when α_0 is set equal to expenditure in the base period, α_i equals the predicted budget share and (5.15) reduces to

$$(5.16)\quad \eta_{ij} = -\delta + \left(\frac{\gamma_{ij}}{w_{it}}\right) - \left(\frac{\beta_i}{w_{it}}\right) w_{jt}.$$

This expression is identical to the formula used by Chalfant (1987) in the linear approximate almost ideal demand system.

Buse (1994) shows that the correct formula for the uncompensated elasticity for the linear approximate almost ideal demand system computed by Green and Alston (1990) can be written as

$$(5.17)\quad \eta_{ij} = -\delta + \frac{\gamma_{ij}}{w_{it}} - \left(\frac{\beta_i}{w_{it}}\right)\left(w_{jt} + \sum_{j=1}^{n} \gamma_{ij} \ln p_{jt}\right)\left(1 + \sum_{j=1}^{n} \beta_i \ln p_{jt}\right)^{-1}.$$

However, at the point of normalisation also this expression reduces to (5.16). Hence, at the point of normalisation, the formulas for the uncompensated elasticities are equal in the nonlinear and the linear approximate almost ideal demand systems, if α_0 is set equal to the logarithm of expenditure in the base period. One way to obtain this is to normalise the sum of the quantities to one at the normalisation point. Expenditure will than equal one, and the logarithm of expenditure, and thereby α_0, zero. This is also true if the Stone price index is replaced by any of the indices suggested by Moschini. Green and Alston (1991) show that the expenditure elasticities, and thereby the compensated elasticities, may differ between the nonlinear and the linear approximate almost ideal demand systems. However, using the same arguments as above, one can show that at the point of normalisation, they are all equal.

2.6 Dynamic Specifications of Demand Systems

The subject of dynamic specification of demand systems has received relatively little attention in the literature. However, some exceptions exist. Following Houthakker and Taylor's (1966) work on single equation habit-formation demand equations, Pollak and Wales (1969) introduced habit formation in the linear expenditure system by including lagged dependent variables in the specification. Theoretical consistency for this approach was shown by Pollak (1970). Habit-formation has later been introduced in other demand system specifications, including the almost ideal demand system (see e.g. Howe *et al.* (1979), Blanciforti and Green (1983) and Alessie and Kapteyn (1991)).

Habit formation is, however, not the only possible reason for dynamics in consumer demand. Pollak (1970) for instance, suggests that contractual obligations or imperfect information may cause some adjustment time to any changes in prices or expenditure. These hypotheses do, however, require a more general dynamic structure than the habit formation model. The only specification that has been able to nest these structures is the error correction specification of Anderson and Blundell (1983; 1984). This specification is based on the framework developed for a production function by Anderson and Blundell (1982). The system of demand functions based on an almost ideal demand system is transformed into an autoregressive distributed lag model by including lags of all the variables in the demand system, and then transformed into an error correction model in the spirit of Davidson *et al.* (1978). Some complications arise in the dynamic system that are apparent in neither the single equation error correction model nor the static demand system specification because of the singular nature of the system and the lagged budget shares. This is solved by Anderson and Blundell, but the dynamic demand system specification they suggest is nonlinear.

The advantage with Anderson and Blundell's specification is that other more restrictive dynamic specifications, such as autoregressive errors and habit formation, as well as the static model are nested inside the general dynamic model. Hence, this specification allows the researcher to test the appropriateness of, for example, the habit formation hypothesis. On the occasions where this framework has been utilised, the hypothesis of more restrictive models is rejected in favour of the most general dynamic specification (Anderson and Blundell, 1983; 1984; Veall and Zimmermann, 1986). As dynamic specification of demand systems is the main scope of this dissertation, this issue will be further discussed on in later chapters. Anderson and Blundell's specification will also be presented in more detail.

2.7 Simultaneity

In Section 2.2, it was shown that direct and inverse demand systems contain the same information about the consumer's preferences. This is true when we know the demand system. The quantity demanded of a good is then easily found if we know the prices at any price level (and vice versa). However, in applied work the aim is to obtain information about the consumer's preferences by estimating demand functions using empirical data. We then have observations only of the transaction price and quantity for each good, possibly together with other variables which may affect either demand or supply (e.g. consumer income and input factor prices). Observations of only prices and quantities will not be sufficient to identify either demand or supply, as we will not be able to tell if price/quantity changes are caused by changes in demand or supply. Accordingly, both price and quantity are in general endogenous in the econometric model.[19] A complete simultaneous equation system or an instrumental variable (IV) approach with supply shifters as instruments is then necessary to obtain consistent estimates of the parameters in the demand function(s). Under some special circumstances, however, the supply functions have a form which makes either the price(s) or quantity(ies) exogenous, giving us the possibility of obtaining consistent estimates of the demand functions without taking the supply side into account. The advantage is that ordinary least squares (OLS) or seemingly unrelated regressions (SUR) estimation then may be used, giving more efficient parameter estimates.[20]

We will now deal with the situation where either quantity or price may be treated as exogenous and how this may be statistically tested for in a single equation framework. The results easily generalise to a system framework and this will be commented on at the end of the section. The review is based on Thurman (1985; 1986; 1987).

---

[19] It should be noted that some authors also worry about the possible endogeneity of expenditure (Deaton, 1986; LaFrance, 1991). While this may be a concern, it does not seem to be too much of a problem under fairly reasonable assumptions, in particular when using time series data (Deaton, 1986). This issue is mostly ignored in applied work.

[20] When the right-hand side variables are uncorrelated with the error terms, they are the most efficient instruments, and an IV approach is reduced to OLS or SUR estimation (Davidson and MacKinnon, 1993).

Thurman bases his exposition on a simultaneous equation system for one commodity. The system is given by;

(7.1) $b_1 q_t + b_2 p_t = X_t' g + e_t,$

(7.2) $c_1 q_t + c_2 p_t = Z_t' h + u_t,$

where $E\left[X_t' \quad Z_t'\right]\left[e_t \quad u_t\right] = 0$, $E(e_t u_t) = 0$, p_t is the price of the commodity, q_t is the quantity and X_t and Z_t are vectors of exogenous variables, each with at least one element which is not common to both vectors.[21] To simplify the discussion, we interpret (7.1) as the demand function and (7.2) as the supply function.

There are two alternative parameter restrictions on the system (7.1), (7.2) which predetermine supply (Thurman, 1986). Each of the two implies its own normalisation of demand. The first is that the supply equation predetermines price, i.e., $c_1 = 0$, giving the following model for the demand function;

(7.3) $q_t = \left(\frac{1}{b_1}\right) X_t' g - \left(\frac{b_2}{b_1}\right) p_t + \left(\frac{e_t}{b_1}\right) = b p_t + X_t' g_1 + e_{1t}.$

With the other restriction the supply equation predetermines quantity, i.e., $c_2 = 0$, giving the following model for the demand function;

(7.4) $p_t = \left(\frac{1}{b_2}\right) X_t' g - \left(\frac{b_1}{b_2}\right) q_t + \left(\frac{e_t}{b_2}\right) = \left(\frac{1}{b}\right) q_t + X_t' g_2 + e_{2t}.$

That is, if supply predetermines price, a direct demand function is appropriate, while if supply predetermines quantity, an inverse demand function is appropriate. If (7.4) is appropriate and one wishes an estimate of the elasticity b, then the inverse of the slope

[21] We will not comment on the necessary condition for a simultaneous equation system to be identified (see Davidson and MacKinnon, 1993), but note that the interpretation of the exogenous variables leaves our system identified.

coefficient in (7.4) is not only consistent, but also equal to the full information maximum likelihood estimator for *b* (Shonkwiler and Taylor, 1984).

Several economic hypotheses are consistent with either (7.3) or (7.4) (Thurman, 1985). In the agricultural economics literature, it is at times argued that supply is more variable than demand, leading to models where price is predetermined (e.g. Wohlgenant and Hahn, 1982). Another argument for predetermined price is that households are price takers. It is important to distinguish between predetermined price and price taking behaviour, as aggregate demand shocks common to all the households will lead to endogenous prices, even if the households are price takers. One might of course argue that such shocks should be explicitly modelled, as they represent a systematic change in preferences (Thurman, 1987). Other arguments for a predetermined price are that prices are set by suppliers based only on cost considerations independent of consumption (Theil, 1975, p. 165), or that supply is provided by a competitive industry with constant returns to scale and a perfectly elastic supply curve (Thurman, 1985).

An argument for predetermined supply for agricultural commodities is that often there exists a relatively fixed length biological production period which leaves supply fixed at any point in time. A similar argument is often used in wild fisheries, where it may be argued that fishermen catch what they can get and land the catch whatever the price (Barten and Bettendorf, 1989; Salvanes and Steen, 1994). Another argument for predetermined supply is of course rationing (Deaton and Muellbauer, 1980b, ch. 2.7).

In most of the literature considering estimation of demand functions, one of the preceeding arguments is used to argue that either price or quantity is predetermined, even if the possibility of a simultaneous equation bias is acknowledged. Thurman (1986) uses a test by Hausman (1978) to statistically test the hypothesis that price or quantity is predetermined.[22]

The Hausman test exploits the fact that both OLS and IV are consistent if the variables in question are exogenous, while only IV is consistent if the variables are endogenous. The test measures the distance between the OLS and IV estimates of the parameters on the variables in question. If the distance is small, one concludes that the estimates converge to the same parameters and that the null hypothesis of exogeneity for the variables in question cannot be rejected. If the distance is large, the estimators are judged to have different probability limits and the null hypothesis can be rejected. Letting b_{OLS} denote the OLS estimates and b_{IV} the IV estimates of the parameters for the variables in question, the Hausman test is given as

(7.5) $$H = (b_{OLS} - b_{IV})' [V(q)]^{-1} (b_{OLS} - b_{IV}),$$

where

(7.6) $$V(q) = V(b_{IV}) - V(b_{OLS}).$$

Under the null hypothesis, the test statistic is distributed as χ^2 with degrees of freedom equal to the number of variables in question.

[22] The test is also known as a Wu-Hausman or a Durbin-Wu-Hausman test as Durbin (1954) and Wu (1973) proposed endogeneity tests which are special cases of Hausman's test.

A problem with the Hausman test in a supply-demand framework is that it can only answer one question at the time, i.e., whether price or quantity is predetermined. To obtain an answer, the researcher must therefore conduct two Hausman tests; one on a direct demand function to test if price is predetermined and one on an inverse demand function to test if quantity is predetermined (Thurman, 1986). If both tests reject the null hypothesis, one should use an IV approach to estimate the demand function. However, if one test rejects and the other does not, we may have one of two outcomes; either the price or quantity are exogenous as indicated by the test where the null cannot be rejected, or the system is simultaneous, but the power of the test where the null cannot be rejected is too low to show this. Thurman (1986) conducts an investigation on how the test power will affect the results, and concludes that: "The relative power result states that we should expect a price-dependent rejection and a quantity-dependent nonrejection only when supply is flat or close to it" (Thurman, 1986, p. 645). That is, the power is weak only when the null hypothesis is, or is close to being true anyway.

Although endogeneity has been considered in only a few studies in demand system specifications, most of the analysis above generalises straightforwardly to the system case. Wahl and Hayes (1990) conducted a Hausman test for predetermined prices using an almost ideal demand system by setting the system on vector form. Eales and Unnevehr (1993) take this kind of analysis a step further towards the single equation approach recommended by Thurman (1986) by deriving an inverse form of the almost ideal demand system, testing for both predetermined prices and quantities. In systems it is also possible to test whether price or quantity is endogenous in a subset of the equations, although Hausman (1978) indicates that the power of the test is weak in such cases. It may also create difficulties if some demand equations are thought to be direct and others inverse, i.e., a mixed demand system. Moschini and Vissa (1993) derive such an expression for a Rotterdam system, but it seems difficult to conduct tests for endogeneity in this framework.

2.8. Derived Demand

In many demand studies the data utilised are not at the consumer level, but at intermediate levels such as import or wholesale level. This may create problems when one is interested in consumer demand, as the data may reflect derived demand from the intermediaries, not the consumer. This may be the case in this dissertation, where import data are used. Both the market structure and the intermediaries' production technology may cause the derived demand functions to deviate from the consumers' demand functions. We will next discuss the relationship between derived demand and consumer demand, and in particular, when they are equal.

The intermediaries' production technology may cause their demand for a commodity to differ from the consumers' demand, since the producers have substitution possibilities in response to changes in the relative prices of input factors (Hicks, 1957; Gardner, 1975; Wohlgenant, 1989). In the case where the intermediaries' production technology uses two inputs, a and b, and is characterised by constant returns to scale, the relationship between the derived demand own-price elasticity for input a, E_a, and the consumer demand own-price elasticity η, may be expressed as (Hicks, 1957, p. 244; Gardner, 1975);

(8.1) $$E_a = \frac{\eta\sigma + e_b(S_a\eta - S_b\sigma)}{e_b + S_a\sigma - S_b\eta}$$

where σ is the elasticity of substitution between the two inputs, e_b is the supply elasticity for input b, and S_a and S_b are the cost shares for inputs a and b respectively. The derived demand elasticity will be less elastic than the consumer demand elasticity if $\sigma < |\eta|$. It will be equal to the consumer demand elasticity if $\sigma = |\eta|$, and it will be more elastic if $\sigma > |\eta|$.

One simpler version of the relationship between consumer demand and derived demand often used in the literature is to assume the derived demand is equal to the consumer demand times the elasticity of price transmission (George and King, 1971), or

(8.2) $$E_a = \eta E_T.$$

The elasticity of price transmission E_T, is the elasticity of the consumer price with respect to the input factor price. However, Gardner (1975) shows that this expression is correct only when the intermediaries' production technology is characterised by fixed factor proportions (i.e., the elasticity of substitution is zero). Equation (8.1) will then reduce to;

(8.3) $$E_a = \frac{e_b S_a \eta}{e_b - S_b\eta}.$$

Note that in this case the derived demand elasticity will always be less elastic than the consumer demand elasticity as $0 = \sigma < |\eta|$.

An interesting question is whether the derived demand elasticity will equal the consumer demand elasticity under any other conditions than $\sigma = |\eta|$. The answer is yes, if the intermediaries' production technology may be represented with only one variable input. If S_a is equal to one and S_b equal to zero, it is easily seen that both (8.1) and (8.3) reduce to

(8.4) $E_a = \eta$.

While a short-run technology with only one variable input factor in each production process does not seem unrealistic for many retailers or wholesalers, other factors such as labour and capital are necessary in the long run. It may therefore be of interest to see how the relationship between the consumer demand and the derived demand elasticities changes with different relationships between two cost shares. This is graphed in Figure 2.1 for four different values of the elasticity of substitution, σ=0, σ=0.5, σ=1 and σ=5. The consumer demand own-price elasticity η is set equal to minus one, and the supply elasticity for input *b*, e_b, is set equal to one. The relationships in the figure are relatively insensitive to the supply elasticity for input *b*, and also to η if the relationship between η and σ is kept constant. In all cases, the derived demand elasticity approaches the elasticity of substitution when the cost share of input *a* approaches zero, and in all cases the derived demand elasticity approaches the consumer demand elasticity when the cost share of input *a* increases until they are equal when the cost share of input *a* is one.

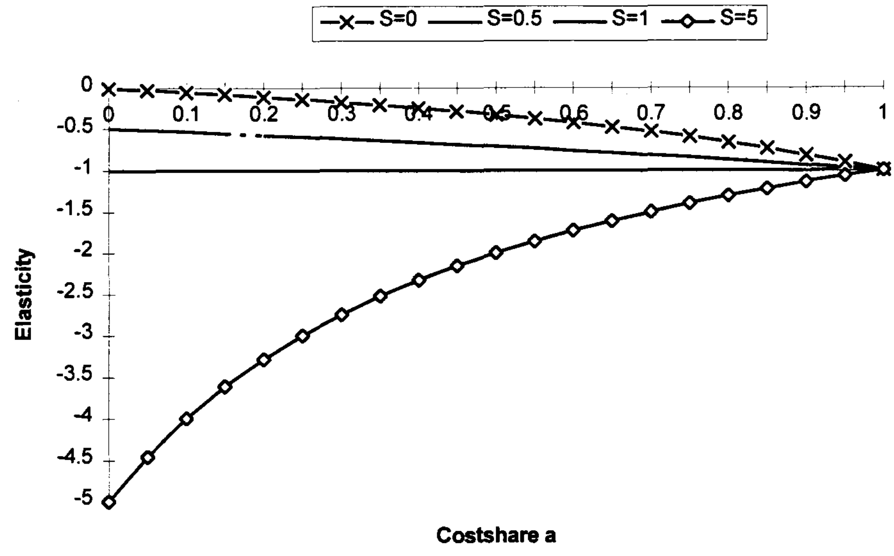


Figure 2.1. The relationship between consumer and derived demand elasticities

The market structure can cause import demand to deviate from consumer demand if the intermediaries have market power or if there is significant domestic production. If the intermediaries have market power, they will drive a wedge between the consumers demand and the derived demand to extract the monopolistic profit. This will be true if the intermediaries have market power in the retail markets (oligopoly) or in the input factor markets (oligoposony), see e.g. Goodwin (1994). Domestic production may cause problems when using import data as the data may not reflect the size of the market.

It should be noted that the issue of derived demand is independent of whether one use a single equation or a system specification for the demand equations. The problem is that data are often available only at an intermediate level, and not at the retail level.

Derived demand for the firms operating at this intermediate level is what the data measure. However, data on output and other factors for these firms are rarely available, preventing the estimation of the intermediate firms' demand. On the other hand, data on some measure of consumer expenditure are mostly available, enabling estimation of equations with the form of consumer demand functions. This has lead to a large literature estimating demand equations based on the consumer theory with data at intermediate levels such as import, export, wholesale or ex-vessel. While single equation specifications have been most common, demand systems, including the almost ideal demand system, have also been used when estimating demand equations with data at an intermediate level. International trade models are one example, and it seems to be no problem to interpret the results as import demand in this case (Alston *et al.*, 1990; Davis and Kruse, 1993).

2.9 On Demand System Specifications

The linear expenditure system was once important as it was the first effort to specify demand equations in accordance with consumer theory. However, it was not considered for the empirical work in this dissertation because of the strict restrictions the functional form imposes on the consumers' behaviour. This is, of course, the reason that this functional form is not commonly used anymore. One reason to prefer the Rotterdam, translog and almost ideal demand systems to other demand system specifications is that in most other demand systems the functional form imposes stricter restrictions on consumer behaviour.

As mentioned above, no clear criteria exist to discriminate between the Rotterdam, translog and almost ideal demand systems. However, with the scope of this dissertation in mind, the features of the systems might be important. The translog is unattractive, because the nonlinear specification makes it difficult to introduce any dynamics. The introduction of further dynamics is also difficult in the Rotterdam system because of the limited dynamics inherent in the differential specification. In particular, error correction models like the specification of Davidson *et al.* (1978) seem to be difficult to derive from the Rotterdam system as it is the levels of the variables which form the long-run relationship. One might also question if all available information is utilised in the Rotterdam specification under all circumstances. For instance Engel and Granger (1987) indicate that with nonstationary cointegrated data series, the levels of the data series must be included to uncover the long-run relationship between the variables in each equation. The linear version of the almost ideal demand system avoids these problems, and does not have any other drawbacks to the author's knowledge. Probably because of its lack of drawbacks, the almost ideal demand system is also the only one of these specifications that has been used in empirical work using the most general dynamic specifications based on error correction specifications (see Anderson and Blundell, 1983; 1984; Veall and Zimmermann, 1986). The almost ideal demand system will therefore be the preferred demand system specification in this dissertation.

REFERENCES

Alessie, R. and A. Kapteyn (1991) "Habit Formation, Interdependent Preferences and Demographic Effect in the Almost Ideal Demand System," *Economic Journal,* 101, 404-419.

Alston, J. M. and J. A. Chalfant (1991) "Can We Take the Con Out of Meat Demand Studies," *Western Journal of Agricultural Economics*, 16, 36-48.

Alston, J. M., C. A. Carter, R. Green, and D. Pick (1990) "Whither Armington Trade Models," *American Journal of Agricultural Economics*, 72, 455-468.

Alston, J. M., K. A. Foster, and R. D. Green (1994) "Estimating Elasticities with the Linear Approximate Almost Ideal Demand System," *Review of Economics and Statistics*, 76, 351-356.

Anderson, G. J. and R. W. Blundell (1982) "Estimation and Hypothesis Testing in Dynamic Singular Equation Systems," *Econometrica,* 50, 1559-1571.

Anderson, G. J. and R. W. Blundell (1983) "Testing Restrictions in a Flexible Demand System: An Application to Consumers' Expenditure in Canada," *Review of Economic Studies,* 50, 397-410.

Anderson, G. J. and R. W. Blundell (1984) "Consumer Non-Durables in the U.K.: A Dynamic Demand System," *Economic Journal,* 94, 35-44.

Anderson, R. W. (1980) "Some Theory of Inverse Demand for Applied Demand Analysis," *European Economic Review,* 14, 281-290.

Ardeni, P. G. (1989) "Does the Law of One Price Really Hold for Commodity prices?," *American Journal of Agricultural Economics,* 71, 661-669.

Banerjee, A., J. Dolado, J. W. Galbraith, and D. F. Hendry (1993) *Co-integration, Error Correction, and the Econometric Analysis of Non-stationary Data*, Oxford: Oxford University Press.

Barten, A. P. (1966) *Theorie en Empirie van een Volledig Stelsel van Vraagvergelijkingen*, Amsterdam: Doctoral Dissertation.

Barten, A. P. (1967) "Evidence on the Slutsky Conditions for Demand Equations," *Review of Economics and Statistics,* 49, 77-84.

Barten, A. P. (1968) "Estimating Demand Equations," *Econometrica,* 36, 213-251.

Barten, A. P. (1969) "Maximum Likelihood Estimation of a Complete System of Demand Equations," *European Economic Review,* 1, 7-73.

Barten, A. P. (1993) "Consumer Allocation Models: Choice of Functional Form," *Empirical Economics,* 18, 129-158.

Barten, A. P. and L. J. Bettendorf (1989) "Price Formation of Fish," *European Economic Review,* 33, 1509-1525.

Barten, A. P. and V. Bohm (1982) "Consumer Theory," In *Handbook of Mathematical Economics*, ed. K. J. Arrow and M. D. Intriligator. 381-429. Amsterdam: North-Holland.

Bird, P. (1986) "Econometric Estimation of World Salmon Demand," *Marine Resource Economics,* 3, 169-182.

Bjørndal, T., K. G. Salvanes, and J. H. Andreassen (1992) "The Demand for Salmon in France: the Effects of Marketing and Structural Change," *Applied Economics,* 24, 1027-1034.

Blanciforti, L. and R. Green (1983) "An Almost Ideal Demand System Incorporating Habits: An Analysis of Expenditures on Food and Aggregate Commounity Groups," *Review of Economics and Statistics*, 65, 511-515.

Blanciforti, L. A., R. D. Green, and G. A. King (1986) U.S. Consumer Behavior Over the Postwar Period: An Almost Ideal Demand System Analysis, University of California, Giannini Foundation Monogrph No. 40.

Blundell, R. W. (1988) "Consumer Behaviour: Theory and Empirical Evidence - A Survey," *Economic Journal,* 98, 16-65.

Buse, A. (1994) "Evaluating the Linearized Almost Ideal Demand System," *American Journal of Agricultural Economics*, 76, 781-793.

Bårdsen, G. (1989) "The Estimation of Error Correction Models," *Oxford Bulletin of Economics and Statistics,* 51, 345-350.

Chalfant, J. (1987) "A Globally Flexible, Almost Ideal Demand System," *Journal of Business and Economics Statistics*, 5, 233-242.

Christensen, L. R., D. W. Jorgenson, and L. J. Lau (1971) "Conjugate Duality and the Transcendental Logarithmic Production Function," *Econometrica,* 39, 255-256.

Christensen, L. R., D. W. Jorgenson, and L. J. Lau (1973) "Transcendental Logarithmic Production Frontiers," *Review of Economics and Statistics,* 55, 28-45.

Christensen, L. R., D. W. Jorgenson, and L. J. Lau (1975) "Transcendental Logarithmic Utility Functions," *American Economic Review,* 65, 283-367.

Cornes, R. (1992) *Duality and Modern Economics*, Cambridge: Cambridge University Press.

Davidson, J. E. H., D. F. Hendry, F. Srba, and S. Yeo (1978) "Econometric Modelling of the Aggregate Time-Series Relationship Between Consumers' Expenditure and Income in the United Kingdom," *Economic Journal,* 88, 661-92.

Davidson, R. and J. G. MacKinnon (1993) *Estimation and Inference in Econometrics*, Oxford: Oxford University Press.

Davis, G. C. and N. C. Kruse (1993) " Consistent Estimation of Armington Demand Models," *American Journal of Agricultural Economics*, 75, 719-723.

Deaton, A. (1986) "Demand Analysis," In *Handbook of Econometrics*, ed. Z. Griliches and M. D. Intriligator. 1767-1839. Amsterdam: North-Holland.

Deaton, A. S. and J. Muellbauer (1980a) "An Almost Ideal Demand System," *American Economic Review,* 70, 312-326.

Deaton, A. S. and J. Muellbauer (1980b) *Economics and Consumer Behavior*, New York: Cambridge University Press.

DeVoretz, D. J. and K. G. Salvanes (1993) "Market Structure for Farmed Salmon," *American Journal of Agricultural Economics,* 75, 227-233.

Diewert, W. E. (1971) "An Application of the Shephard Duality Theorem: A Generalized Leontief Production Function," *Journal of Political Economy,* 79, 481-507.

Diewert, W. E. (1974) "Applications of Duality Theory," In *Frontiers of Quantitative Economics*, ed. Intriligator M. D. and Kendricks D. A. 106-171. Amsterdam: North Holland.

Diewert, W. E. (1982) "Duality Approaches to Microeconomic Theory," In *Handbook of Matematical Economics*, ed. K. J. Arrow and M. D. Intriligator. Amsterdam: North-Holland.

Duesenberry, J. S. (1949) *Income, Saving, and the Theory of Consumer Behavior*, Cambridge, Mass.: Harvard University Press.

Durbin, J. (1954) "Errors in Variables," *Review of the International Statistical Institute,* 22, 23-32.

Eales, J. S. and L. J. Unnevehr (1988) "Deamand for Beef and Chicken Products: Separability and Structural Change," *American Journal of Agricultural Economics,* 70, 521-532.

Eales, J. S. and L. J. Unnevehr (1993) "Simultaneity and Structural Change in U.S. Meat Demand," *American Journal of Agricultural Economics,* 75, 259-268.

Engle, R. F. and C. W. J. Granger (1987) "Co-integration and Error Correction: Representation, Estimation and Testing," *Econometrica,* 55(2), 251-276.

Gardner, B. L. (1975) "The Farm-Retail Price Spread in a Competitive Food Industry," *American Journal of Agricultural Economics,* 57, 399-409.

George, P. S. and G. A. King (1971) *Consumer Demand for Food Commodities in the United States with Projections for 1980*, Giannini Foundation Monograph No. 26, University of California, Berkeley.

Goodwin, B. K. (1994) "Oligopsony Power: A Forgotten Dimension of Food Marketing," *American Journal of Agricultural Economics*, 76, 1163-1165.

Green, R. and J. M. Alston (1990) "Elasticities in AIDS models," *American Journal of Agricultural Economics*, 72, 442-445.

Green, R. and J. M. Alston (1991) "A Clarification and Extension," *American Journal of Agricultural Economics*, 73, 874-875.

Hausman, J. A. (1978) "Specification Tests in Econometrics," *Econometrica*, 46, 1251-1271.

Heien, D. and C. R. Wessells (1988) "The Demand for Dairy Products: Structure, Prediction and Decomposition," *American Journal of Agricultural Economics*, 70, 219-228.

Heien, D. and C. R. Wessells (1990) "Demand Systems Estimation with Microdata: A Censored Regression Approach," *Journal of Business and Economic Statistics*, 8, 365-371.

Hicks, J. R. (1957) *The Theory of Wages*, Gloucester, Mass: Peter Smith.

Houthakker, H. S. and L. D. Taylor (1966) *Consumer Demand in the United States: Analysis and Projections*, Cambridge, MA: Harvard University Press.

Howe, H., R. A. Pollak, and T. J. Wales (1979) "Theory and Time Series Estimation of the Quadratic Expenditure System," *Econometrica,* 47, 1231-1247.

Johnson, J. A., E. H. Oksanen, M. R. Veall, and D. Fretz (1992) "Short-run and Long-run Elasticities for Canadian Consumption of Alcoholic Beverages: An Error-correction Mechanism/Cointegration Approach," *Review of Economics and Statistics,* 74, 64-74.

Johnston, R. S. and D. M. Larson (1994) "Focusing the Search for Giffen Behavior," *Economic Inquiry*, 32, 168-174.

Klein, L. R. and H. Rubin (1947-48) "A Constant Utility Index of the Cost of Living," *Review of Economic Studies,* 15, 84-87.

LaFrance, J. T. (1986) "The Structure of Constant Elasticity Demand Models," *American Journal of Agricultural Economics*, 68, 543-552.

LaFrance, J. T. (1991) "When is Expenditure "Exogenous" in Separable Deamnd Models? ," *Western Journal of Agricultural Economics*, 16, 49-62.

Moschini, G. (1995) "Units of Measurement and the Stone Price Index in Demand System Estimation," *American Journal of Agricultural Economics*, 77, 63-68.

Moschini, G. and A. Vissa (1993) "Flexible Specification of Mixed Demand Systems," *American Journal of Agricultural Economics,* 75, 1-9.

Pashardes, P. (1993) "Bias in Estimating the Almost Ideal Demand System with the Stone Index Approximation," *Economic Journal*, 103, 908-915.

Phlips, L. (1974) *Applied Consumption Analysis*, Amsterdam: North-Holland.

Pollak, R. A. (1970) "Habit Formation and Dynamic Demand Functions," *Journal of Political Economy,* 78, 745-763.

Pollak, R. A. and T. J. Wales (1969) "Estimation of the Linear Expenditure System," *Econometrica,* 37, 611-628.

Pollak, R. A. and T. J. Wales (1992) *Demand System Specification and Estimation*, Oxford: Oxford University Press.

Prais, S. J. and H. S. Houthakker (1955) *The Analysis of Family Budgets*, Cambridge: Cambridge University Press.

Salvanes, K. G. and D. J. DeVoretz (1993) "Household Demand for Fish and Meat Products: Separability and Demographic Effects," Preliminary Version.

Salvanes, K. G. and F. Steen (1994) "Testing for Relative Performance between Seasons in a Fishery," *Land Economics,* 70, 431-447.

Salvanes, K. G, K. Vaage, and F. Asche (1994) "World Demand for Salmon and Environmental Incidents: Dynamics and Structural Stability." Centre for Fishery Economics, Norwegian School of Economics and Business Administration.

Shonkwiler, J. S. and T. G. Taylor (1984) "The Implications of Estimating Market Demand Curves by Least Squares Regression," *European Review of Agricultural Economics*, 11, 107-118.

Steen, F. (1994) "Defining Market Boundaries Using a Multivariate Cointegration Approach: The EC market(s) for Salmon One or Several?" Department of Economics, Simon Fraser University. Discussion Paper No. 94-06.

Stone, J. R. N. (1954a) "Linear Expenditure Systems and Demand Analysis: an Application to the Pattern of British Demand," *Economic Journal,* 64, 511-527.

Stone, J. R. N. (1954b) *The Measurement of Consumers' Expenditure and Behaviour in the United Kingdom*, Cambridge: Cambridge University Press.

Theil, H. (1965) "The Information Approach to Demand Analysis," *Econometrica,* 33, 67-87.

Theil, H. (1975) *Theory and Measurement of Consumer Demand*, Vol. I, Amsterdam: North-Holland.

Thurman, W. N. (1985) "Endogeneity Testing in a Supply and Demand Framework." North Carolina State University, Department of Economics and Business, Faculty Working Paper No. 72.

Thurman, W. N. (1986) "Endogeneity Testing in a Supply and Demand Framework," *Review of Economics and Statistics,* 68, 638-646.

Thurman, W. N. (1987) "The Poultry Market: Demand Stability and Industry Structure," *American Journal of Agricultural Economics,* 69, 30-37.

Veall, M. R. and K. F. Zimmermann (1986) "A Monthly, Dynamic Consumer Expenditure System for Germany with Different Types of Households," *Review of Economics and Statistics,* 68, 256-264.

Wahl, T. I. and D. J. Hayes (1990) "Demand System Estimation with Upward-Sloping Supply," *Canadian Journal of Agricultural Economics,* 38, 107-122.

Wellman, K. F. (1992) "The US Retail Demand for Fish Products: An Application of the Almost Ideal Demand System," *Applied Economics*, 24, 445-457.

White, H. (1984) *Asymptotic Theory for Econometricians*, San Diego: Academic Press.

Wickens, M. R. and T. S. Breusch (1988) "Dynamic Specification, the Long-Run and the Estimation of Transformed Regression Models," *Economic Journal,* 98, 189-205.

Wohlgenant, M. K. (1989) "Demand for Farm Output in a Complete System of Demand Functions," *American Journal of Agricultural Economics,* 71, 241-252.

Wohlgenant, M. K. and W. F. Hahn (1982) "Dynamic Adjustment in Monthly Consumer Demand for Meats," *American Journal of Agricultural Economics,* 64, 553-557.

Wu, D. (1973) "Alternative Tests of Independence Between Stochastic Regressors and Disturbances," *Econometrica,* 41, 733-750.

3: THE SALMON MARKET

3.1 Introduction

In this chapter, several issues in relation to the salmon market, and particularly the salmon market in the European Union, will be reviewed. This includes topics such as supply sources for salmon, market structure, and a review of earlier demand studies of the salmon market. The market in the European Union is given more attention in this study than other markets because the European Union is the primary market for Norwegian salmon. Of particular interest is the market structure faced by Norwegian salmon farmers. Only fresh, frozen and smoked salmon will be considered, as these are the product forms of interest when considering farmed salmon. Canned salmon will not be dealt with in this dissertation, since most researchers do not consider canned salmon to be a significant substitute for other salmon product forms. The data sets used in this dissertation will be presented and some issues related to the data set will also be discussed.

This is only a brief overview, and several other texts give a more detailed analysis of the salmon industry, such as Shaw and Muir (1987) and Bjørndal (1990), and in Norwegian, Bjørndal (1987), Bjørndal, Salvanes, Andreassen and Sæter (1990), Bjørndal and Salvanes (1992) and Bjørndal and Salvanes (1995a). The production structure in the salmon industry will not be considered here. However, Shaw and Muir (1987) and Bjørndal (1990) also cover that aspect, together with several other studies, notably Salvanes (1989; 1993), Salvanes and Tveterås (1992) and Bjørndal and Salvanes (1995b).

This chapter will be organised as follows: In Section 3.2, the supply of salmon, both wild caught and farmed, will be discussed. In Section 3.3, the substitution possibilities in the salmon market are discussed. The market structure is reviewed in Section 3.4. In Section 3.5, a presentation of the primary markets for salmon is given, while a review of earlier studies of the demand for salmon and categories thereof is offered in Section 3.6. The data set is presented in Section 3.7, where also several issues related to the data set are discussed.

3.2 The Supply of Salmon

Since the early 1980s, the supply of salmon has increased significantly worldwide. Moreover, a new dimension has been added to the market with the introduction of farmed salmon. Production of farmed salmon has increased from virtually nothing in 1980 to around 33 percent of total supply in 1992 with a quantity of 307,200 metric tons (see Table 3.1), and the production is still rising. Norway is the predominant producer of farmed salmon, and although Norwegian farmers' market share has declined recently, they still provide over 40 percent of the world supply of farmed salmon.

Wild-caught salmon consists of two groups, Atlantic and Pacific salmon. While there is only one species of Atlantic salmon, the Pacific salmon consists of six different species; chinook, chum, coho, pink and sockeye and local to Japanese waters; cherry. Cherry salmon is fairly similar to pink, and is often reported together with pink. Pacific salmon dominates the supply of wild salmon with about 98 percent of the supplied quantity. Only four countries land Pacific salmon. With the average share of supply in parentheses, these countries are; USA (44%), Japan (28%), USSR/Russia (16%) and Canada (12%) (Bjørndal, 1990). Wild Atlantic salmon is found in all countries in the Northern Atlantic. However, the quantities are small, and in many places there is a moratorium on commercial harvesting of salmon. The relative importance of the different species in the total supply of wild salmon in the period 1980-1985 may be seen in Table 3.2. Chum, pink and sockeye make up the largest part of the supply with almost 90%. The supply of chinook and coho is much smaller, but still significantly larger than Atlantic and cherry. The relative importance of pink and sockeye has also been increasing recently (Bjørndal and Salvanes, 1992).

Table 3.1. Production of salmon 1980-92

Year	World catch of wild salmon (1,000 tons)	Production of farmed salmon (1,000 tons)	Total salmon production (1,000 tons)	Farmed salmon share of total production
1980	537.4	6.9	544.3	1%
1981	649.0	11.8	660.8	2%
1982	557.2	16.3	573.5	3%
1983	678.7	24.4	703.1	3%
1984	624.1	32.4	656.5	5%
1985	793.5	46.6	840.1	6%
1986	675.0	69.4	744.4	9%
1987	650.2	84.3	734.5	11%
1988	612.0	139.7	751.7	19%
1989	705.2	203.8	909.0	22%
1990	804.0	273.8	1,077.8	25%
1991	875.5	299.9	1,175.4	26%
1992	635.4	307.2	942.6	33%

Source: Bjørndal (1990), *Globefish Highlights* 1/1991 and 1/1992, Bjørndal and Salvanes (1995a), *FAO: Fisheries Statistics: Catches and landings.*

Table 3.2. Annual average catches of wild salmon by species 1980-1985

(1,000 tons)

Atlantic (*Salmo salar*)	11.2
Chinook (*O. tshawytscha*)	21.2
Coho (*O. kisutch*)	35.3
Sockeye (*O. nerka*)	135.7
Pink (*O. gorbuscha*)	238.0
Chum (*O. keta*)	200.9
Cherry (*O. masuo*)	3.6
Total	645.9

Source: Bjørndal (1990).

Salmon aquaculture focuses on three species, Atlantic, chinook and coho. In Table 3.3 the production of farmed salmon is shown for the period 1986-92, and in Table 3.4 the production is divided into Atlantic and Pacific salmon for the period 1986-91. Note that the data from the two sources are not entirely comparable. Atlantic is the most important, and provides about 80% of the quantity produced of farmed salmon. Several Pacific rim nations (Canada, Chile, Australia) are also producing farmed Atlantic salmon, and it is therefore expected that Atlantic salmon will continue to be the main species in salmon aquaculture (Bjørndal and Salvanes, 1992). Norway is by far the largest producer of farmed salmon, supplying more than 50% of the quantity of Atlantic and 40% of all farmed salmon. However, Norway's market share is declining as salmon aquaculture is established and expands in more countries. In Europe, Scotland and the Faroe Islands are major suppliers, and Chile and Canada supply significant quantities as well. Japan is the largest supplier of farmed Pacific salmon, although the production recently has expanded quickly also in other countries along the Pacific rim (Bjørndal and Salvanes, 1992).

Table 3.3. Production of farmed salmon (Atlantic and Pacific) 1986-92 (1,000 tons)

	1986	1987	1988	1989	1990	1991	1992
Norway	44.8	46.5	78.7	111.3	146.0	132.4	128.0
Scotland	10.3	12.7	18.0	28.6	32.4	40.6	36.1
Ireland	1.2	2.2	4.1	5.2	6.3	9.3	10.5
Chile	1.1	1.8	4.2	8.8	23.3	34.1	46.5
Faroe I.	1.9	2.5	4.0	8.0	13.0	20.0	18.0
Iceland	0.2	0.5	1.2	1.6	2.9	2.9	3.8
USA	1.3	2.4	4.2	3.6	3.9	7.1	7.0
Canada	1.0	3.1	9.8	16.8	21.2	27.0	28.7
Australia	-	-	-	0.4	1.8	2.5	2.6
Japan	7.0	11.6	14.0	18.0	21.0	21.0	21.0
New Zealand	0.6	1.0	1.5	1.5	2.0	3.0	5.0
Total	**69.4**	**84.3**	**139.7**	**203.8**	**273.8**	**299.9**	**307.2**

Source: Bjørndal and Salvanes (1995a).

Table 3.4. Production of farmed salmon by species 1986-91 (1,000 tons)

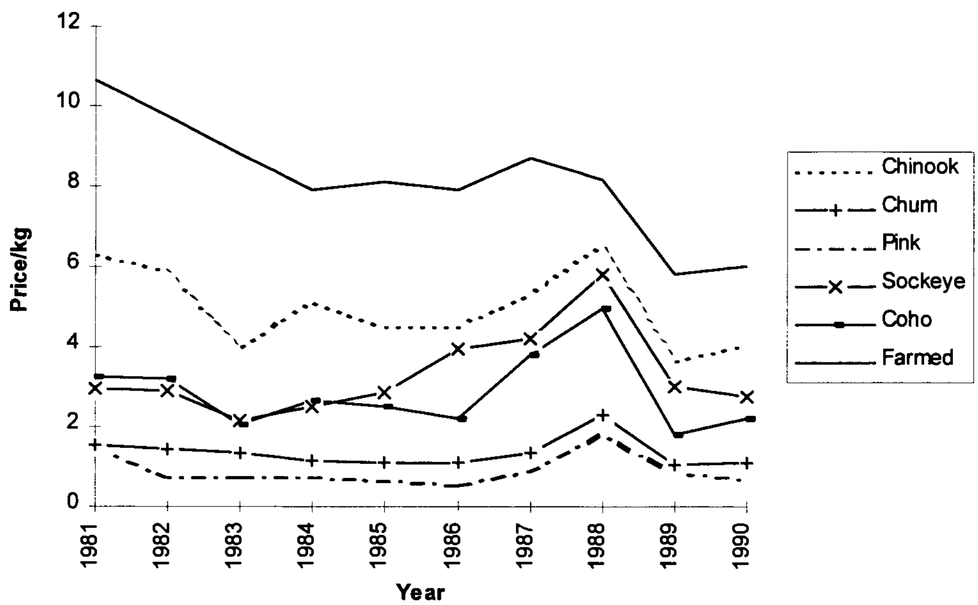
	1986	1987	1988	1989	1990	1991
Atlantic						
Norway	45.5	47.4	80.0	115.0	158.0	160.0
Scotland	10.4	13.0	18.0	29.0	33.4	46.6
Ireland	1.2	2.2	4.7	6.2	8.0	8.0
Chile	-	0.1	0.6	1.7	9.5	11.0
Faroe I.	1.9	2.5	4.0	3.0	13.0	20.0
Iceland	0.7	0.7	1.3	1.5	3.0	5.0
Canada	0.8	1.0	1.6	2.0	9.9	10.8
Australia	-	-	1.0	2.0	4.0	6.0
Total Atlantic	**60.5**	**66.9**	**112.5**	**160.4**	**238.8**	**261.4**
Pacific						
Japan	7.0	12.0	14.0	18.0	21.5	21.0
Canada	1.0	1.2	6.0	12.4	12.2	15.1
Chile	1.5	2.0	4.0	7.0	13.8	14.0
USA	1.5	1.5	2.7	1.9	2.5	5.0
New Zealand	0.6	1.0	1.5	1.5	2.0	3.0
Total Pacific	**11.6**	**17.7**	**28.2**	**40.8**	**52.0**	**56.1**

Source: *Globefish Highlights*, no. 1/1992 (preliminary numbers for 1990 and 1991).

3.3 Substitution Possibilities in the Market for Salmon

The quality of the different species of salmon differs a great deal, and there are many different views on which products belong to the same market segment. Atlantic salmon is generally regarded as the highest quality. Pacific salmon is sometimes divided into two groups; high-value and low-value salmon. Different relationships may exist between the products in the different groups. Other seafood products, both white fish and crustaceans, may also be substitutes for salmon or some product forms/species of salmon. We will here first comment on the relationships between the different species of salmon, and particularly on the division of Pacific salmon into high- and low-valued species.

In Figure 3.1, the real prices of the different salmon species are shown using Norwegian export data for farmed Atlantic salmon and data from the *Fisheries of the United States* for the Pacific species. There is no doubt that Atlantic salmon commands the highest price. Note however, that the price of farmed Atlantic salmon has decreased relative to the other species during the 1980s. This may be explained by the large increase in the supply of farmed salmon. It must also be noted that from around 1985, there has existed a separate market for wild-caught Atlantic salmon, which commands a higher price than farmed Atlantic salmon.



Source: *Fisheries of the US* for the Pacific species and Statistics Norway for Farmed salmon.

Figure 3.1. Real prices of different salmon species 1981-1990. Prices in real USD (1990=1).

There exists some disagreement in the literature on which Pacific species are reasonably viewed as close substitutes to Atlantic salmon. Bjørndal and Salvanes (1992) argue that chinook and coho are the Pacific species most similar in quality to Atlantic salmon, and accordingly the Pacific species most likely to be close substitutes for Atlantic salmon. An aggregate of high-valued salmon containing chinook and coho has also been used as a substitute price when modelling the demand for farmed

Atlantic salmon (e.g. DeVoretz and Salvanes, 1993). However, as may be seen in Figure 3.1, also sockeye is clearly a high-valued species, and has actually commanded a higher price than coho from 1985 on. Herrmann and Lin (1988) and Herrmann, Mittelhammer and Lin (1993) therefore used an aggregate of high-valued salmon containing chinook, coho and sockeye as substitute for farmed salmon.[1] In some studies, only the highest valued Pacific species, chinook, is used as the substitute for farmed salmon (e.g. Herrmann and Lin, 1988). There is no disagreement about categorising chum and pink as low-valued salmon.

One explanation as to why sockeye, which according to Figure 3.1 clearly belongs to the high-valued species, is not treated as a close substitute to Atlantic salmon may be that it traditionally has been canned while chinook and coho have been consumed fresh. However, this has changed a great deal over the last decades as the share of sockeye being canned has declined as better processing opportunities have become available. Sockeye is now increasingly marketed as fresh or frozen (Bjørndal, 1990). Another reason for not treating sockeye as a close substitute to Atlantic salmon, in particular when considering regional markets (i.e., the EU or the US), is that most sockeye is consumed in Japan. Also chum and pink were traditionally canned, but here also fresh and frozen product forms become more important, although these species still are canned to a large extent.

The question of whether sockeye is a close substitute for Atlantic salmon may be important. From Table 3.2, one can see that the quantity of landed sockeye is about two and one half times that of chinook and coho together. Hence, while farmed salmon production is much larger than the supply of high-valued Pacific salmon if high-valued Pacific salmon is taken to be only chinook and coho, the supply of high-valued Pacific salmon has been larger than farmed salmon for most of the last decade

[1] It should here be noted that there are regional differences in preferences with respect to the different Pacific species. In particular, sockeye is very well regarded in Japan, while coho is preferred to sockeye in the United States.

if sockeye is included. As sockeye mostly is consumed in Japan, while the other high-valued species are preferred in the European Union and the United States, the question whether sockeye is a close substitute to Atlantic salmon also depends on whether there exist separate regional salmon markets or one world market.

Viewing the price movements in Figure 3.1, one might also question the division of Pacific salmon into different subgroups. The relationship between the prices of Pacific species seems to be quite stable, and the prices seem to move along the same paths, although volatility is greater for the high-valued species. Except for the downward trend, the price of farmed Atlantic salmon also seems to have moved with the other prices. This is particularly true in the last period covered by the figure. This might indicate that all salmon species belong to the same market, even though the relationship can be closer for species with fairly equal price levels. Note however that as long as the different salmon species are not perfect substitutes, one must expect some differences also in the price paths of the different species, as the quantity available of each species differs each year. In particular for wild salmon there are large fluctuations in the quantity available each year because of different strengths in the salmon runs.

Many studies are also using an aggregate of all salmon or product forms thereof (Bird, 1986; Wessells and Wilen, 1993; 1994; Asche, Salvanes and Steen, 1994).[2] From Figure 3.1, this may be reasonable as the relationship between the prices of the Pacific species seems to be quite stable, although volatility is greater for the high-valued species. Except for the downward trend, the price of farmed Atlantic salmon seems to have the same movements as the other prices.[3] When other species of salmon cannot be used as substitutes, other species of fish or crustaceans are used. In addition, beef,

[2] Wessells and Wilen (1993; 1994) consider two product forms of salmon, fresh and salted, in Japan. Asche, Salvanes and Steen (1994) also consider two product forms, fresh and frozen, in the European Union.

[3] A problem with an all salmon aggregate is, of course, that the composition of the aggregate differs between observations as the quantity available of the different species changes.

pork and poultry have also been tried (Bird, 1986). All these possible substitutes are chosen on *a prori* assumptions. Recently, there have been market delineation tests which may question some of the substitutes in the European Union. Steen (1994) finds that fresh, frozen and smoked salmon compete in the same market segment and Asche, Salvanes and Steen (1994) indicate that a crustaceans aggregate may belong to this market segment. However, Gordon, Salvanes and Atkins (1993) conclude that salmon does not belong to the same market segment as cod and turbot. This also implies that it is unlikely that other medium and low-valued species of white fish belong to the same market segment as salmon.

An interesting question when considering the substitution possibilities in the salmon market, is when do the product forms compete. Salmon is consumed as an appetiser or at lunch tables in its smoked form, or as a main dish based on the fresh or frozen product form. It therefore seems unlikely that fresh and frozen salmon compete with smoked salmon in their final uses. However, fresh and frozen salmon are the main inputs for the smoking industry, and one would therefore expect a close connection between the import prices (and farm gate prices in salmon producing countries) of fresh and frozen salmon and smoked salmon if the smoking industry is competitive. Hence, at this market level, fresh and frozen salmon imported as an input for the smoking industry clearly competes with imports of smoked salmon. As most of the Pacific salmon imports to Europe are frozen, Pacific salmon is probably a weaker substitute for fresh farmed salmon than for frozen farmed salmon. Different types of white fish are on the other hand mostly consumed as main dishes, and are therefore probably stronger substitutes for fresh than for frozen and smoked salmon.

3.4. Market Structure

The structure of the salmon market has received a lot of attention. In particular, the question of whether some of the suppliers of farmed salmon have market power, at least in some markets, has been raised. Many people in the industry hold this view.

Several authors have also argued that this is the case, and that it is reasonable to treat Norway and Scotland as units (DeVoretz and Salvanes, 1988; Herrmann and Lin, 1988). Norway especially, with its large market share for farmed salmon may have market power potential if acting as a unit. Scotland may also have a degree of market power if the market for fresh salmon in the European Union is viewed as a separate market (see Tables 3.5, 3.6 and 3.7 for total imports in the European Union and for imports from Norway and Scotland for fresh, frozen and smoked salmon).

In Scotland, the industry is fairly concentrated, while in Norway access to the industry and the size of each farm is regulated by the government. In both countries the farmers are organised. In Scotland, this is voluntary. It was mandatory until the end of 1991 in Norway, where the Fish Farmers Sales Organisation (Fiskeoppdretternes Salgslag (FOS)), had an exclusive right to administer the farmgate sales and also provided generic marketing for Norwegian salmon.[4] The FOS did not have the authority to disallow any sales, but all buyers had to be licensed, and the FOS could remove the licence if the buyer did not abide by its rules. The FOS gained information about the buyers' activities by having access to their accounts and by collecting payment from buyers for the farmers. The main reason the Norwegian government gave the FOS its powers was to ensure a balanced development of the industry. The government used licensing of farms as a tool in regional policy to promote growth in remote areas.

The ability to set a minimum price for farmgate sales, combined with the fact that Norwegian farmers provided more than 40% of the world supply of farmed salmon and 50% of Atlantic salmon, may well indicate that the FOS thought it had market

[4] The FOS organised advertising campaigns and set quality standards. The Norwegian Superior salmon designation was introduced by the FOS as they divided Norwgian salmon into three quality classes; superior, ordinary and production.

power.[5] Others seem to have shared this view. As late as June 1992, the Commission in the European Union condemned the Norwegian and Scottish producers for price collusion (Steen, 1994).

However, there are those who argue against the proposition that the FOS, and its Scottish counterpart, had any market power. This view is taken by Bjørndal and Schwindt (1988) and Bjørndal and Salvanes (1995a). The main argument advanced is that farmed salmon cannot be viewed as a market on its own. Farmed salmon has many substitutes, most notably wild-caught salmon, as farmed salmon provides only a limited part of total world supply of salmon. Other seafood products may also be substitutes for salmon.

Neither producers nor consumers have preferred trading partners and the producer organisations may not have the opportunity to restrict the actions of the individual farmers. The fact is that the minimum price was a nonbinding constraint throughout the 1980s as salmon was traded at prices above the minimum level during that period. In recent studies, there does not seem to be any empirical evidence indicating that the European salmon market is not competitive (DeVoretz and Salvanes, 1993; Steen, 1994; Asche, Salvanes and Steen, 1994). Although these results do not necessarily generalise to other salmon markets, it seems that at least the European salmon market is competitive.

As a postscript it should be noted that there was strong downward pressure on the price of salmon in the period 1989-1991 due to increased production of farmed salmon and record landings of wild Pacific salmon. To stabilise price, the FOS initiated a large freezing programme in 1990, and in the period 1990-91, about 88,000 tons of salmon were frozen. However, the FOS did not succeed in stabilising the price

[5] It should be noted that the market shares for Norwegian farmers early in the 1980s were significantly higher than the 40% and 50% used here. These are the percentages in 1992, when Norwegian farmers had their lowest market share ever (see Table 3.3).

and a huge inventory of frozen salmon, together with low prices, forced the FOS into bankruptcy in November 1991.

The largest quantities of Pacific salmon, particularly chum, pink and sockeye, are landed in late summer and fall when the large salmon runs occur.[6] Because of this, there has been some speculation that producers of farmed salmon, and in particular Norway, may have market power on a seasonal basis (DeVoretz and Salvanes, 1993; Steen, 1994). However, there exists only weak, and not statistically significant evidence in that direction. Accordingly, it does not seem likely that producers are able to exploit the seasonality of the salmon runs to gain market power in periods. It must also be noted that frozen Pacific salmon and small quantities of fresh chinook and coho are available all year along together with other types of seafood. This should limit the opportunity to exploit market power. It should also be noted that in Alaska, there have been allegations that Japanese purchasers and Alaskan processors had monopsony power to some extent after 1988, which was used to keep prices low.

Some trade barriers also exist in the salmon market. The European Union charges a duty on all salmon imports from outside the Union. The duty is fairly low, 2%, for fresh or frozen salmon, whole or filets. However, there is a large smoking industry in in the European Union countries (particularly in France, Denmark and Germany) which is protected by a 13% duty on imports of smoked salmon. In periods of low salmon prices, Scottish and Irish farmers actively lobby for higher trade barriers on salmon from outside the European Union. Such trade barriers have not yet been implemented, but may become a problem in the future for producers outside the Union. In November 1991, European Union producers received some protection as a minimum price was implemented for a limited period, although at a fairly low level, on salmon imports into the European Union. Minumum prices have also been

[6] Some runs occur in the spring. Most of the spring runs are chinook, which because of this, also is known as spring salmon. There are also spring runs of chum.

implemented several times after this. However, the European smoking industry gives the outside producers some defence, as these processors are interested in an inexpensive input. On April 16, 1991, following dumping charges from domestic producers, the United States was effectively closing that market to Norwegian producers as Norwegian imports now face a high tariff, on average 26 percent, but depending on firm.

3.5. The Demand for Salmon

The most important markets for salmon are the European Union, Japan and the United States. Japan is the world's largest consumer of seafood, and although it produces significant quantities of salmon domestically, Japan also imports large quantities. The imported salmon are mostly wild-caught salmon from Canada and the United States, but farmed salmon are becoming increasingly important. This is particularly true for the Pacific rim producers in Australia, Canada, Chile and New Zealand, but increasingly also for European producers, in particular Norway. A survey of the Japanese market may be found in Wessells (1990).

The market in the United States is mostly own-supplied by wild-caught Pacific salmon, but imported farmed salmon has gained access to some market segments such as the restaurant sector, but also supermarkets, particularly on the east coast. The advantage with farmed salmon is that it is a high-quality product and there is some degree of delivery reliability. This market was important to Norwegian farmers in the last half of the eighties with over 20% of Norwegian exports in some years. However, the high levy that was imposed on Norwegian salmon in April 1991, closed this market for Norwegian farmers. This market is today supplied by Canadian, Chilean and domestically produced farmed salmon. A brief review of the development of U.S. imports of fresh salmon can be found in Anderson (1992).

Table 3.5. Fresh salmon imported by the European Union (values in 1000 ECU (1992=100), quantities in metric tonns).

Year	Total imports		Supply source for imports										French imports	
			Canada		USA		Norway		Scotland		Other			
	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity
1981	62,078	5,485	101	16	70	8	51,302	4,530	7,536	632	3,069	299	28,164	2,487
1982	82,482	7,408	207	13	69	10	69,299	6,195	9,455	825	3,452	365	37,859	3,378
1983	108,746	10,590	200	32	556	88	90,819	8,602	9,894	993	7,277	875	45,483	4,412
1984	131,217	12,785	37	6	570	72	107,962	10,339	16,309	1,693	6,339	675	52,398	5,283
1985	185,762	17,002	140	24	793	112	147,259	13,197	23,362	2,176	14,209	1,493	68,207	6,270
1986	209,282	26,996	170	26	153	18	168,267	21,600	26,481	3,449	14,211	1,903	88,584	11,731
1987	300,009	35,807	27	6	371	59	226,981	26,521	30,517	3,652	42,113	5,569	124,986	15,028
1988	389,261	52,471	450	70	3,171	581	305,656	40,697	42,044	5,617	37,941	5,506	151,804	21,389
1989	442,941	78,879	150	30	3,374	787	336,022	59,164	51,656	9,553	51,738	9,345	174,881	32,991
1990	508,707	97,005	382	95	1,190	344	391,722	73,622	44,599	8,534	70,814	14,410	202,985	41,027
1991	509,268	108,700	276	87	480	181	377,805	79,983	58,460	12,203	72,247	16,246	207,027	46,491
1992	597,303	124,477	157	44	544	160	449,996	93,374	49,399	9,780	97,207	21,119	232,127	50,661

Source: Eurostat

Table 3.6. Frozen salmon imported by the European Union (values in 1000 ECU (1992=100), quantities in metric tons).

Year	Total imports		Supply source for imports										French imports	
			Canada		USA		Norway		Scotland		Other			
	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity
1981	278,369	29,553	92,554	10,302	109,700	13,782	25,805	2,098	1,729	185	48,582	3,186	134,477	14,234
1982	290,835	30,688	100,891	10,353	121,942	15,233	20,620	1,797	2,602	309	44,779	2,996	143,999	14,958
1983	278,804	34,314	98,146	12,466	100,152	15,699	34,888	2,785	2,188	261	43,431	3,103	137,552	16,708
1984	307,273	33,799	104,538	10,890	127,784	16,746	31,507	2,889	3,218	325	40,225	2,949	171,982	18,248
1985	285,251	34,496	87,205	10,421	116,954	17,384	33,567	3,073	2,520	301	45,005	3,317	130,862	16,256
1986	241,028	38,223	67,729	11,880	93,496	18,475	34,545	4,108	2,630	447	42,629	3,313	125,393	21,744
1987	271,107	41,065	78,680	13,265	112,491	19,662	33,086	4,040	3,831	600	43,019	3,498	153,738	24,380
1988	262,381	36,663	62,038	8,017	93,048	13,457	74,103	9,893	3,408	438	29,784	4,858	157,352	20,813
1989	176,959	32,638	35,091	6,467	45,201	9,798	73,426	12,426	1,816	314	21,425	3,633	106,435	19,655
1990	212,193	46,483	28,303	6,403	47,091	13,840	114,379	21,587	2,882	542	19,539	4,111	133,500	28,985
1991	230,954	54,206	24,451	5,909	44,555	14,781	142,434	29,260	2,656	463	16,858	3,793	138,208	34,552
1992	203,943	49,345	24,287	6,582	53,890	19,079	100,574	18,614	5,000	1,029	20,192	4,041	117,327	31,610

Source: Eurostat

Table 3.7. Smoked salmon imported by the European Union (values in 1000 ECU (1992=100), quantities in metric tons).

Year	Total imports		Supply source for imports										French imports	
			Canada		USA		Norway		Scotland		Other			
	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity
1981	9,292	319	629	22	72	1	1,351	60	5,299	166	1,941	70	3,782	111
1982	10,589	407	426	15	307	14	1,369	62	6,109	209	2,378	107	3,878	110
1983	10,399	433	95	5	38	2	2,328	133	5,380	180	2,558	113	4,416	140
1984	9,617	483	267	28	27	1	2,877	121	5,113	165	1,333	168	4,917	257
1985	16,767	662	399	18	23	0	3,489	160	8,389	292	4,467	192	7,274	248
1986	23,764	1,146	555	33	363	25	6,018	315	10,460	434	6,368	339	9,286	388
1987	30,836	1,402	879	47	595	43	6,983	373	17,475	699	4,906	240	12,622	547
1988	36,767	1,549	1,301	60	103	4	5,263	272	22,666	865	7,434	348	12,836	521
1989	44,371	2,517	645	42	207	19	11,449	842	25,690	1,261	6,381	353	19,368	1,217
1990	44,111	2,681	683	39	20	0	8,089	595	28,193	1,617	7,126	430	17,103	1,200
1991	50,608	3,317	641	44	86	4	8,572	925	32,883	1,873	8,425	471	21,062	1,267
1992	51,217	3,247	612	61	90	3	7,949	593	33,834	2,038	8,732	552	22,803	1,413

Source: Eurostat

The European market is the most important for farmed Atlantic salmon. In other parts of the world farmed salmon is used almost exclusively in the high quality, high valued fresh market. In Europe farmed salmon is also used in lower valued processed product forms. However, until the last half of the 1980s, fresh salmon was regarded as an upscale product consumed in restaurants, and farmed salmon was produced for this market. Historically, the European countries with large smoking industries used the cheaper frozen Pacific salmon as the main input. However, this situation has changed. Now the European smoking industry buys most of the frozen farmed salmon and also significant quantities of fresh farmed salmon. Farmed salmon has also gained access in new markets such as the supermarkets. Tables 3.5, 3.6 and 3.7 show imports of salmon into the European Union for the three product forms fresh, frozen and smoked salmon. As can be seen, there has been a tremendous growth in imports for all product forms. Note that fresh salmon has overtaken frozen salmon as the most important product form. It should also be noted that re-exports are excluded from the data, as discussed in Section 3.7.[7]

Some of the explanation for the strong position for farmed salmon is that in Europe, transportation costs work in favour of farmed salmon as much of the farmed salmon is produced in Europe (see Table 3.3), while most of the wild salmon is landed in the Pacific. Also, as may be seen from Figure 3.1, the price of farmed Atlantic salmon has recently declined relative to the Pacific species, making farmed salmon more competitive. The effect of the cheaper and more available farmed salmon can be seen in the market shares in Europe for Canada and the United States, the main exporters of Pacific salmon. The combined market share of Canada and the United States was about 60% of all salmon in the early 1980s, while in 1992 it was under 10%. For their major product form, frozen salmon, the market share was reduced from about 75% in the early 1980s to about 40% in 1992. It should be noted that the market in Europe

[7] This is the major reason for the deviations from the numbers reported in Steen (1994), who used the same data source, but also counted re-exports.

has increased dramatically from 1981 to 1992, so the lost market share does not reflect a decrease in quantity of salmon from North America.

Denmark has gained a special position in the European salmon market as a broker for salmon (Bjørndal and Salvanes, 1992). Denmark is the second largest importer of salmon in Europe, after France. However, most of this salmon is re-exported to other countries inside the European Union. Although a substantial part is re-exported without any processing (40% in the late 1980s (Bjørndal *et al.*, 1990)), there has emerged a large Danish processing industry. Most of the processing is smoking (Bjørndal *et al.*, 1990). The emergence of this industry can be explained by the different duties on fresh and frozen salmon (2%) and smoked salmon (13%) imported into the European Union. Recently, there has also emerged an export oriented smoking industry in the United Kingdom. However, it is based on domestically produced salmon and the export quantities are small compared to Denmark.

In several European countries, there is a significant salmon processing industry. The most common processing activity by far is smoking, especially in France and Germany, as well as Denmark. Smoked salmon processed inside the European Union is traded in fairly large quantities between the members of the Union, but only Denmark and the United Kingdom are net exporters (Bjørndal *et al.*, 1990). In France, the largest importer of salmon in Europe, the smoking industry purchases almost 50% of all salmon imports (Monfort, 1988). The smoking industry purchases almost all frozen salmon imports, as well as significant quantities of fresh salmon. As noted above, the smoking industry is also protected by a much higher import duty (13%) than fresh and frozen salmon (2%). Imports of smoked salmon from outside the European Union mostly is a speciality, and the quantity imported is small. The European Union imported on average seven times as much frozen as smoked salmon each year in the period 1981-1992.

3.6 Demand Studies

The demand for salmon, or product forms thereof, has been studied extensively in the economics literature. Until the early 1980s, the attention was directed toward the demand for canned salmon, the principal product form made from the Pacific salmon. As canned salmon is not considered in this dissertation, this literature will not be reviewed here. An excellent survey may be found in Herrmann (1990, ch. 3). [8]

It must be noted that the studies reviewed cover many different markets using different model specifications over different time periods. One must therefore be careful when comparing results, as the results from each study are directly applicable only for the market being studied over the period covered by the data set. Note also, that depending on the model specification, different measures of income/expenditure are used. While one might argue in all cases that the measure used is compatible with some weak separability assumption, these weak separability assumptions need not be compatible.

DeVoretz (1982) was the first to study the demand for product forms other than canned salmon when he estimated a demand function for an aggregate of Canadian fresh and frozen salmon.[9] Kabir and Ridler (1984) also considered the demand for fresh and frozen salmon, but only for Canadian Atlantic salmon. Kabir and Ridler's study was probably the first motivated by the emergence of farmed salmon as it became a traded commodity around 1980, even though the quantity was minor compared with the quantities traded today. Bird (1986) estimated the total world demand for salmon.

[8] This dissertation focuses on market structure, and approaches using market research techniques will not be considered here. If this is of interest, see Wessells and Anderson (1992) and references therein.
[9] DeVoretz (1982) also estimates the demand for Canadian canned salmon.

Table 3.8. Estimated elasticities from demand studies of salmon

Market/ Dep. var.	Time horiz.	Data period	Ownp. Elast.	Crossp. Elast	Substitute	Exp./Inc Elast.	Author
Canada/ All	LR	1948/ 1976	-8.33	2.38	Tuna	2.04	DeVoretz (1982)
Canada/ Fresh	LR	1955/ 1981	-13.51	-	-	5.12	Kabir and Ridler (1984)
Canada/ Fresh	LR	1955/ 1981	-10.00	-	-	3.83	
World All	SR	1958/ 1982	-2.15	0.22	Tuna	10.29	Bird (1986)
World All	LR	1958/ 1982	-0.88	0.81	Tuna	0.33	
USA/ Norw. s.	LR	jan83/ mar87	-1.97	0.56	Pacific salmon	4.51	Herrmann and Lin (1988)
EU/ Norw. s.	LR	jan83/ mar87	-1.83	0.37	Pacific salmon	2.73	
France/ Norw. s.	SR	jan81/ jun90	-1.06	1.07	High. val. fish.	1.88	Bjørndal,Salvanes, Andreassen (1992)
France/ Norw. s.	LR	jan81/ jun90	-1.30	1.31	High. val. fish.	2.30	
USA/ Norw. s.	LR	jan85/ dec88	-2.89	-	-	-	Bjørndal, Gordon and Singh (1993)
World Norw. s.	LR	jan83/ dec88	-2.38	0.95	Pacific Salmon	2.11	DeVoretz and Salvanes (1993)
USA/ Norw. s.	LR	1.q.83/ 4.q.88	-1.350	0.448	Pacific s. High. val.	3.279	Herrmann, Mittelhammer and Lin (1993)
EU/ Norw. s.	LR	1.q.82/ 4.q.88	-1.941	0.354	Pacific s. High. val.	2.589	
Japan/ Norw. s.	LR	1.q.83/ 4.q.88	-2.282	2.589	Pacific s. High. val.	3.681	
EU/ Pac.high	LR	1.q.82/ 4.q.88	-1.883	1.395	Pacific s. Low. val.	2.454	
EU/ Pac.low	LR	1.q.82/ 4.q.88	-1.160	0.342	Pacific s. High. val.	0.608	
Japan/ Pac.high	LR	1.q.83/ 4.q.88	-3.019	2.557	Pacific s. Low. val.	2.958	
Japan/ Pac.low	LR	1.q.83/ 4.q.88	-1.918	2.713	Pacific s. High. val.	1.720	
Japan(s)/ Fresh s.	LR	jan80/ dec89	-2.11	-	-	1.10	Wessells and Wilen (1993)
Japan(n) Fresh s.	LR	jan80/ dec89	-1.21	-	-	1.09	
Spain/ Norw.	SR	jan85/ dec89	-1.06	-	-	3.28	Bjørndal, Gordon, Salvanes (1994)

salmon	LR	jan85/ dec89	-1.78	-	-	5.51	
Italy Norw.	SR	jan85/ dec89	-0.66	0.69	High. val. white fish	7.22	Bjørndal, Gordon, Salvanes (1994)
salmon	LR	jan85/ dec89	-1.27	1.34	High. val. white fish	13.85	
Japan/ Fresh s.	LR	jan80/ dec89	-1.28	-	-	1.29	Wessells and Wilen (1994)
Japan(s) Fresh.	LR	jan80/ dec89	-2.21	-	-	1.09	
Japan(n) Fresh	LR	jan80/ dec89	-1.19	-	-	1.08	
EU/ Fresh	LR	jan81/ dec92	-3.728	1.373	Frozen s.	0.239	Asche, Salvanes and Steen (1994)
EU/ Frozen	LR	jan81/ dec92	-2.569	2.757	Fresh s.	0.454	

LR=long run SR=short run[10]

Following growth in farmed salmon production, a number of studies of demand for both farmed and wild-caught salmon appeared in the late 1980s and early 1990s (Herrmann and Lin; 1988; Bjørndal, Gordon and Salvanes, 1992; Bjørndal, Salvanes and Andreassen, 1992; Herrmann, Mittelhammer and Lin, 1992; 1993; Bjørndal, Gordon and Singh, 1993; DeVoretz and Salvanes, 1993; Wessells and Wilen 1993; 1994; Bjørndal, Gordon and Salvanes, 1994; Asche, Salvanes and Steen, 1994). An overview of the results from the studies is given in Table 3.8.[11] In several of the studies results from alternative specifications are reported. From these studies only one model (the one preferred by the authors if this is indicated) is reported here. In the studies where a system containing many goods is estimated (Wessells and Wilen,

[10] There is some disagreement in the literature of what is a long-run relationship. I take the stand held in the time series literature (e.g. Banerjee *et al.*, 1993), in regarding a static model as a long-run relationship. The static model is regarded as a long-run relationship because it is implicitly assumed that the adjustment after, for example, a price change is instantaneous. When the data series is nonstationary, a static regression also provides the parameters in the cointegration vector provided that the data series indeed form a long-run relationship. For a model to provide a short-run relationship, the model must be dynamic, as it is only in this case that further adjustment will take place in the following periods.

[11] The results from Herrmann, Mittelhammer and Lin (1992) are excluded as they only report elasticities for Japan for each month.

1993; 1994; Asche, Salvanes and Steen, 1994), only the salmon categories relevant to this dissertation are reported. There also exists a substantial literature concerned with the demand for salmon in unpublished working papers. With a few exceptions, there will be no attempt to cover this literature here.

The market studied, the aggregation level of the data, and the model specification vary a great deal in the different studies. In the early studies (DeVoretz, 1982; Kabir and Ridler, 1984; Bird, 1986), price dependent models were preferred as wild-caught salmon was the subject of interest.[12] In the more recent studies where the interest is mostly on farmed salmon, quantity dependent models, possibly estimated with instrumental variables (IV) procedures to control for simultaneity, have been preferred. Most of these studies specify single equation demand functions. Recently Wessells and Wilen (1993; 1994) and Asche, Salvanes and Steen (1994) have used system specifications.

With some exceptions, little attention has been paid to dynamics. Bird (1986) and Asche, Salvanes and Steen (1994) use error correction representations based on the Bårdsen transformation (Bårdsen, 1989). Simpler dynamics are also introduced in some of the studies. Bjørndal, Salvanes and Andreassen (1992) and Bjørndal, Gordon and Salvanes (1994) use a habit formation model and Wessells and Wilen (1993; 1994) use a model with autoregressive errors.

There has been some discussion on whether it is reasonable to assume that prices are predetermined in the quantity dependent specifications. Herrmann and Lin (1988) and Herrmann, Mittelhammer and Lin (1992; 1993) implicitly assume that prices are not predetermined and estimate their demand equation with IV procedures. Bjørndal, Salvanes and Andreassen (1992), Bjørndal, Gordon and Singh (1993), Bjørndal,

[12] DeVoretz (1982) reports the results from a price dependent model, but also reports that he has estimated a simultaneous equation model.

Gordon and Salvanes (1994) and Wessells and Wilen (1993; 1994) assume that prices are predetermined, as the demand equations are estimated without any supply shifters as instruments. DeVoretz and Salvanes (1993) and Asche, Salvanes and Steen (1994) test the assumption of predetermined prices using a Hausman test. In both cases the hypothesis of predetermined prices cannot be rejected, and predetermined prices therefore seem to be a plausible assumption. However, the results are directly applicable only for the markets being studied over the period covered by the data set. Hence, one must be careful if one wishes to generalise this result. In particular, note that only the demand for farmed salmon is studied by DeVoretz and Salvanes (1993) and only the European market, where farmed salmon dominates, is studied by Asche, Salvanes and Steen (1994).

Although the results differ a great deal, some general conclusions can be drawn. The studied categories of salmon seem to be own-price elastic. The only exceptions are Bird's (1986) long-run elasticity and Bjørndal, Gordon and Salvanes' (1994) short run elasticity in Spain. However, with the exception of Asche, Salvanes and Steen (1994), the magnitude of the elasticities seem to be lower in the markets where farmed salmon has a strong position. In most markets, salmon seems to have substitutes and salmon seems to be expenditure elastic. However, in the studies using system specifications (Wessells and Wilen, 1993; 1994; Asche, Salvanes and Steen, 1994), which are theoretically consistent, the expenditure elasticities are notably lower and, in the last case, also inelastic.

3.7 The Data Set

The data sets used in this dissertation consist of import data to the European Union for three product forms of salmon. The data sets originate from Eurostat via the Norwegian Seafood Export Council in Tromsø (the exact product categories are given in section 3.7.1). The raw data sets consist of the cumulative total import value in ECU and total imported quantity in metric tons, to all countries in the European Union for the three product forms fresh, frozen and smoked salmon, on a monthly basis from January 1981 to December 1990, and monthly import value and quantity from January 1991 to December 1992.[13],[14] This gives 144 observations. These data series are aggregated over the countries in the European Union to obtain data for the European Union.

A problem with the data set is that all observations are missing in nine months in the period 1981-85, because the data tapes for these months are missing from Eurostat.[15] To reduce this problem to two missing observations, the data are aggregated to a quarterly level in the chapters where the long-run properties of demand is the focus of interest. This gives 48 observations. We will not lose any long-run information on the demand for salmon in this process, only short-run seasonality. This leaves two remaining missing observations are the first quarter (March) of 1982 and the fourth quarter (December) of 1984 in this data set. The missing observations are filled by interpolation.

As noted, both Scotland and Ireland produce farmed salmon and Denmark has a significant re-export of salmon. There is also a large smoking industry in several of the member countries in the European Union. This may cause problems in the analyses. The import data do not provide any information about salmon produced and consumed domestically in the United Kingdom and Ireland. However, the United Kingdom and Ireland, which are the only countries producing salmon in the European Union, produce a fairly small share of the total supply of salmon in the European Union (under 10% in most of the period 1981-1992), and the part that is exported is accounted for in the data set. Since between 40% and 50% of the Scottish and even

[13] The data are cumulative only until 1990. From then on the monthly imported values and quantities are registered.
[14] The Norwegian Seafood Exports Council also had the tapes available for 1980. However, as observations in nine of the twelve months were missing, I chose to exclude 1980.
[15] The lacking months are: February 81; May 81; November, 81, January 82, January 83, March 83, May 84, December 84, January 85.

more of the Irish production is exported, less than 5% of the total salmon supply is left out of the data set. Hence, the domestic consumption should not cause serious problems. Re-export between members of the European Union, and particularly in processed forms, may cause greater problems. If this is included, the re-exported salmon will be counted twice, first when it is imported as fresh/frozen, and then when it is re-exported, either in the same product form or as smoked salmon. As the primary interest in this dissertation is the demand facing Norwegian farmers, exports from the United Kingdom and Ireland are included in the data. Exports from all other countries in the European Union are excluded to avoid counting the salmon twice, as these countries do not have a salmon aquaculture industry.

3.7.1 Data Description and Variable Definition

The data sets were extracted from Eurostat's COMTEX data base's Chapter 3; Fish and Crustaceans, Molluscs and other aquatic invertebrates. Prior to 1988 fresh salmon was registered as one aggregated product; No. 030103 Fresh or chilled Pacific salmon (*Oncorhyncus SSP*), Atlantic salmon (*Salmon Salar*) and Danube Salmon (*Hucho Hucho*). In 1988 a new nomenclature and new categories were introduced. The fresh salmon category was then disaggregated into no. 03021200, Fresh or chilled salmon and no. 03041013, Fresh or chilled fillets of salmon. Hence, to ensure compatibility with the data until 1988, these two groups were aggregated into one. A parallel harmonisation was done for frozen salmon. Prior to 1988 frozen salmon was in the category no. 030104 Frozen Pacific salmon (*Oncorhyncus SSP*), Atlantic salmon (*Salmon Salar*) and Danube Salmon (*Hucho Hucho*). From 1988 this was disaggregated into three categories, no. 03031000 frozen Pacific salmon, no. 03032200 frozen Atlantic salmon and no. 03042012 frozen fillets of all salmon. Here, these groups are also reaggregated for the years 1988-92 in the data set. The smoked salmon category changed code in the nomenclature from no. 030233 to no. 03054100, while retaining the definition Smoked Pacific salmon (*Oncorhyncus SSP*), Atlantic salmon (*Salmon Salar*) and Danube Salmon (*Hucho Hucho*).

The product categories used by Eurostat limits the possible disaggregation. In particular, it is not possible to separate Pacific and Atlantic salmon and the different species of Pacific salmon (chinook, chum, coho, pink and sockeye), or separate the product forms into more disaggregated product forms. Whole salmon and filets are not separated until 1988, disallowing disaggregation if one is to keep a sufficiently long data set for the econometric analysis. These points may cause problems as the aggregation is not necessarily consistent (see Deaton and Muellbauer (1980, ch. 6) for a discussion of aggregation issues). In particular, shares of the different salmon species may differ between periods because of different quantities available, and the relative price between the species may also differ if they are not perfect substitutes. The same may be true for the product forms in the frozen salmon category, where filets constitute a significant share (around 10%) at the end of the sample. This is not a problem for fresh salmon, where the filets share is stable at around 1%. It should be noted that these problems are common to most demand studies, and are present to some extent in all the studies of salmon demand reviewed above.

3.7.2 Seasonality

Seasonality may cause unnecessary noise in the data set, and in the literature on seasonality it is generally recommended that seasonality is removed if it is not of particular interest (Sims, 1974; Wallis, 1974; Sims, 1993; Hansen and Sargent, 1993). As the data sets in this dissertation consist of quarterly data in most chapters, and information about the long-run properties of salmon demand is the focus in these chapters, this seasonality will be removed.

The data series for value and quantity for the different products are deseasonalised using seasonal (quarterly) dummy variables. This procedure is discussed by several authors, see Frisch and Waugh (1933), Lovell (1963), Jorgenson (1964) and Davidson and MacKinnon (1993, ch. 19.6). In this approach, each data series is regressed against a set of deterministic variables that include appropriate seasonal dummies. This regression may be written as

(7.1) $\bar{y}_i = D_T\alpha + D_s\beta + \varepsilon$,

where $\bar{y}_i$ is the raw data series, D_T is a vector of deterministic components including a constant term and possible deterministic trends, D_s is a vector of seasonal dummies, α and β are parameters to be estimated and ε is white noise. The deseasonalised data series are generated purging the original data series of seasonal factors or

(7.2) $y_i = \bar{y}_i - D_s\beta$,

where y_i is the deseasonalised data series. Note that it is only the seasonal factors that are removed, each data series still contains other deterministic components. This method of removing deterministic seasonality is relatively common in empirical works (Osborn *et al.*, 1988; Gordon *et al.*, 1993). There exist more advanced nonlinear methods of removing seasonality (Osborn *et al.*, 1988; Harvey, 1989), but the subject will not be pursued further here, as it is beyond the scope of this dissertation.

REFERENCES

Anderson, J. L. (1992) "Salmon Market Dynamics," *Marine Resource Economics*, 7, 87-88.

Asche, F., K. G. Salvanes, and F. Steen (1994) "Market Delineation and Demand Structure," Centre for Research in Economics and Business Administration. Working Paper no. 106/94.

Banerjee, A., J. Dolado, J. W. Galbraith, and D. F. Hendry (1993) *Co-integration, Error Correction, and the Econometric Analysis of Non-stationary Data*, Oxford: Oxford University Press.

Bird, P. (1986) "Econometric Estimation of World Salmon Demand," *Marine Resource Economics,* 3, 169-182.

Bjørndal, T. (1987) *Fiskeoppdretts¢konomi* (The Economics of Aquaculture), Oslo: Cappelen.

Bjørndal, T. (1990) *The Economics of Salmon Aquaculture*, Oxford: Blackwell.

Bjørndal, T., D. V. Gordon, and K. G. Salvanes (1992) "Markets for Salmon in Spain and Italy," *Marine Policy,* 16, 338-344.

Bjørndal, T., D. V. Gordon, and K. G. Salvanes (1994) "Elasticity Estimates of Farmed Salmon Demand in Spain and Italy," *Empirical Economics,* 4, 419-428.

Bjørndal, T., D. V. Gordon, and B. Singh (1993) "A Dominant Firm Model of Price Determination in the US Fresh Salmon Market: 1985-1988," *Applied Economics,* 25, 743-750.

Bjørndal, T. and K. G. Salvanes (1992) "Marknadsstruktur i den Internasjonale Laksemarknaden og Noreg sin Strategiske Posisjon" (Market Structure in the International Salmon Market and Norway's Strategic Position). NOU 1992:36. Norges Offentlige Utredninger.

Bjørndal, T. and K. G. Salvanes (1995a) *Perspektiv på Fiskeoppdrett: Mellom Marknad og Regulering* (Perspectives on Aquaculture: Between Market and Regulation), Oslo: Det Norske Samlaget.

Bjørndal, T. and K. G. Salvanes (1995b) "Gains from Deregulation? An Empirical Test for Efficiency Gains in the Norwegian Fish Farming Industry," *Journal of Agricultural Economics,* 46, 113-126.

Bjørndal, T., K. G. Salvanes, and J. H. Andreassen (1992) "The Demand for Salmon in France: the Effects of Marketing and Structural Change," *Applied Economics,* 24, 1027-1034.

Bjørndal, T., K. G. Salvanes, J. H. Andreassen, and J. Aarsand Sæter (1990) "Produksjons- og Marknadstilhøve for Oppdrettslaks i den Europeiske Felleskapen (EF) (Production- and Market Opportunities for Farmed Salmon in the European Community (EC))." Senter for Anvent Forskning. SAF Report no. 9/90.

Bjørndal, T. and R. Schwindt (1988) "An International Analysis of the Industrial Economics of Salmon Aquaculture." Institute of Fisheries Economics, Norwegian School of Economics and Business Administration. Working Paper 3/88.

Bårdsen, G. (1989) "The Estimation of Error Correction Models," *Oxford Bulletin of Economics and Statistics,* 51, 345-350.

Davidson, R. and J. G. MacKinnon (1993) *Estimation and Inference in Econometrics*, Oxford: Oxford University Press.

Deaton, A. S. and J. Muellbauer (1980) *Economics and Consumer Behavior*, New York: Cambridge University Press.

DeVoretz, D. (1982) "An Econometric Demand Model for Canadian Salmon," *Canadian Journal of Agricultural Economics,* 30, 49-60.

DeVoretz, D. and K. G. Salvanes (1988) "Demand for Norwegian Farmed Salmon: A Market Penetration Model," (Proceedings from the 4th meeting of the International Institute of Fiseries Economics and Trade, 1988). SAF-Arbeidsnotat no. 25/88.

DeVoretz, D. J. and K. G. Salvanes (1993) "Market Structure for Farmed Salmon," *American Journal of Agricultural Economics,* 75, 227-233.

Frisch, R. and F. W. Waugh (1933) "Partial Time Regressions as Compared with Individual Trends," *Econometrica,* 1, 387-401.

Gordon, D. V., K. G. Salvanes, and F. Atkins (1993) "A Fish Is a Fish Is a Fish: Testing for Market Linkage on the Paris Fish Market," *Marine Resource Economics,* 8, 331-343.

Hansen, L. P. and T. J. Sargent (1993) "Seasonality and Approximation Errors in Rational Expectation Models," *Journal of Econometrics,* 55, 21-55.

Harvey, A. (1989) *Forecasting, Structural Time Series Models and the Kalman Filter*, Cambridge: Cambridge University Press.

Herrmann, M., R. C. Mittelhammer, and B. H. Lin (1992) "Applying Almon-Type Polynomials in Modelling Seasonality of the Japanese Demand for Salmon," *Marine Resource Economics,* 7, 3-13.

Herrmann, M. L., R. C. Mittelhammer, and B. H. Lin (1993) "Import Demand for Norwegian Farmed Atlantic Salmon and Wild Pacific Salmon in North America, Japan and the EC," *Canadian Journal of Agricultural Economics,* 41, 111-125.

Herrmann, M. L. and B. H. Lin (1988) "The Demand and Supply of Norwegian Atlantic Salmon in the United States and the European Community," *Canadian Journal of Agricultural Economics,* 38, 459-471.

Jorgenson, D. W. (1964) "Minimum Variance, Linear, Unbiased Seasonal Adjustment in Economic Time Series," *Journal of the American Statistical Association,* 59, 681-725.

Kabir, M. and N. B. Ridler (1984) "The Demand for Atlantic Salmon in Canada," *Canadian Journal of Agricultural Economics,* 32, 560-568.

Lovell, M. C. (1963) "Seasonal Adjustment of Economic Time Series," *Journal of the American Statistical Association,* 58, 993-1010.

Monfort, M. C. (1988) "The Salmon Market and Smoking Industry in France." Centre for Applied Resaerch. SAF Report no. 19/88.

Osborn, D. S., A. P. L. Chui, J. P. Smith, and C. R. Birchenhall (1988) "Seasonality and the Order of Integration for Consumption," *Oxford Bulletin of Economics and Statistics,* 50, 361-377.

Salvanes, K. G. (1989) "The Structure of the Norwegian Fish Farming Industry: An Empirical Analysis of Economies of Scale and Substitution Possibilities," *Marine Resource Economics*, 6, 349-373.

Salvanes, K. G. (1993) "Public Regulation and Production Factor Misallocation: A Restricted Cost Function Approach for the Norwegian Aquaculture Industry," *Marine Resource Economics*, 8, 50-64.

Salvanes, K. G. and R. Tveterås (1992) "Kostnadsoversikt i Norsk Matfiskoppdrett 1982-90: Intertemporale og Regionale Produktivitetsskilnader" (A Survey of Costs in Norwegian Aquaculture 1982-90: Intertemporal and Regional Productivity Differences). NOU 1992:36.

Shaw, S. A. and J. E. Muir (1987) *Salmon: Economics and Marketing*, London: Croom Helm.

Sims, C. A. (1974) "Seasonality in Regression," *Journal of the American Statistical Association,* 62, 618-626.

Sims, C. A. (1993) "Rational Expectations Modeling With Seasonally Adjusted Data," *Journal of Econometrics,* 55, 9-19.

Steen, F. (1994) *Testing for Market Boundaries and Oligopolistic Behavior: An Application to the European Market for Salmon.* Ph.D. Dissertation, Norwegian School of Economics and Business Administration.

Wallis, K. F. (1974) "Seasonal Adjustment and Relations Between Variables," *Journal of the American Statistical Association*, 69, 18-31.

Wessells, C. R. (1990) *An Economic Analysis of the Japanese Salmon Market: Consumption Patterns, the Role of Inventories and Trade Implications*. Ph.D. Dissertation, University of California, Davis.

Wessells, C. R. and J. L. Anderson (1992) "Innovations and Progress in Seafood Demand and Market Analysis," *Marine Resource Economics*, 7, 209-288.

Wessells, C. R. and J. E. Wilen (1993) "Economic Analysis of Japanese Household Demand for Salmon," *Journal of the World Aquaculture Society*, 24, 361-378.

Wessells, C. R. and J. E. Wilen (1994) "Seasonal Patterns and Regional Preferences in Japanese Household Demand for Seafood," *Canadian Journal of Agricultural Economics*, 42, 87-103.

4: A SYSTEM APPROACH TO THE DEMAND FOR SALMON IN THE EUROPEAN UNION

4.1 Introduction[1]

During the last decade there have been a number of studies of salmon demand using time series data (DeVoretz, 1982; Kabir and Ridler, 1984; Bird, 1986; Herrmann and Lin, 1988; Bjørndal, Salvanes and Andreassen, 1992; Bjørndal, Gordon and Singh, 1993; DeVoretz and Salvanes, 1993; Herrmann, Mittelhammer and Lin, 1993; Wessells and Wilen, 1993, 1994).[2] With the exception of Wessells and Wilen (1993; 1994), a common feature of all these studies is the use of a single equation approach to the specification of each demand function and a varying degree of attention to the dynamic properties of the data. Cross-equation interactions between the demand functions have been ignored together with the time series properties of the data series. Also, the estimated demand function will be in accordance with economic theory only under very restrictive assumptions (Deaton and Muellbauer, 1980a, ch. 3). An approach using a system of demand equations may avoid this problem as the adding up, homogeneity and symmetry restrictions implied by economic theory are easily imposed. The lack of attention to the time series properties of the data may also be a

[1] This chapter also appears as Asche (1996).

[2] It should be noted that the demand functions in Herrmann and Lin (1988) and Herrmann, Mittelhammer and Lin (1993) are parts of a larger equilibrium model. However, each demand function is a double log single equation equation and does not allow imposition of adding up, homogeneity and symmetry restrictions except under very restrictive circumstances (see Deaton and Muellbauer (1980a, Ch. 3)).

problem, as most economic data series are found to be nonstationary. This may cause problems with spurious regressions or estimates with nonstandard distributions (Phillips, 1986; 1991; Engle and Granger, 1987), but may be solved through the concept of cointegration and a correct estimation technique (Phillips and Hansen, 1990; Hansen, 1992).

We will estimate the demand for fresh, frozen and smoked salmon in the European Union for the period 1984-1992 using the almost ideal demand system (AIDS) of Deaton and Muellbauer (1980b). By estimating this system, we will obtain better knowledge of the relationship between the three most important high-valued product forms of salmon.[3] It is expected that this analysis will confirm that fresh and frozen salmon are substitutes, but it will also provide some new information. In particular, the above mentioned studies do not provide any information about smoked salmon, and little information about frozen salmon. Expenditure elasticities for the three different product forms will also be of interest.

The data series are all found to be nonstationary, but cointegrated. The Fully Modified Least Squares (FMLS) estimator of Phillips and Hansen (1990) will therefore be utilised. This estimator is obtained by nonparameterically correcting the ordinary least squares (OLS) estimates for both impacts from unit root distributions and autocorrelation. The FMLS estimator has earlier been utilised to estimate an almost ideal demand system system by Chambers (1993) on aggregate consumption data. We will follow his approach, but will in addition take care of possible drifts in the

[3] By restricting attention to high-valued salmon, canned salmon is excluded since it is primarily produced from lower quality Pacific salmon.

nonstationary data series and the equilibrium relationships as suggested by Hansen (1992).

This chapter will be organised as follows. In Section 4.2, we will explore the time series properties of the data using an Augmented Dickey-Fuller test (Dickey and Fuller, 1979; 1981) and present the basic almost ideal demand system to test for cointegration. In Section 4.3, the FMLS estimator will be presented. The empirical results are presented in Section 4.4, before some concluding remarks are given in Section 4.5.

4.2 Data and Model Formulation

The data set consists of import data from the European Union's trade statistics, Eurostat, and was made available for this study by the Norwegian Seafood Export Council in Tromsø (see Chapter 3.7). The data set contains deseasonalised data series on value and quantity of quarterly imports to the European Union of fresh, frozen and smoked salmon for the period 1984(1)-1992(4).[4,5] The deseasonalisation of the data series is done as described by Jorgensen (1964), by removing deterministic seasonality with quarterly dummy variables. Real values were obtained using OECD's consumer price index for the European Union. To analyse the time series properties of the data series, Augmented Dickey-Fuller tests (Dickey and Fuller, 1979; 1981) were undertaken for each of the price and expenditure share series and on total expenditure on the three goods. The results are presented in Table 4.1.[6] The null hypothesis of a

[4] This leaves a slight bias in the data set as national consumption is not included for the producing countries inside the Union. Inside the European Union, only the UK and Ireland are producing salmon, and as the domestic consumption of salmon in these two countries is small compared to the total demand in the European Union, the error this introduces in the data is small. See also the discussion in Chapter 3.7.

[5] The data set used in this paper is three years shorter than the data sets used in the other chapters in this dissertation. This is because this chapter was the first to be written, and it was written before the final data sets were ready. As the paper is published in Asche (1996) in this form, I chose to present these results here. However, the results are not significantly altered by using the full data sets. The uncorrected Stone price index is used in the almost ideal demand system here for the same reason.

[6] All estimation and tests in this chapter were done with the econometric software package Shazam (White, 1978).

unit root can not be rejected for any of the data series at a 10% significance level. We will therefore proceed under the assumption that all the data series contain a unit root.

Table 4.1. Unit root tests

Variable	Test Statistic	Number of lags
Fresh salmon price	-0.711	1
Frozen salmon price	-1.024	0
Smoked salmon price	-0.467	0
Fresh salmon share	-0.741	1
Frozen salmon share	-2.211	3
Smoked salmon share	-1.026	3
Expenditure	-0.293	2

Critical value is -2.93 at a 5% level and -2.60 at a 10% level (Fuller, 1976).

We will estimate the system of demand functions using the almost ideal demand system system of Deaton and Muellbauer (1980b).[7] Each equation in the demand system may be written as;

$$(1) \qquad w_{it} = \alpha_i + a_{iT}t + \sum_j \gamma_{ij} \ln p_{jt} + \beta_i \ln(X_t / P_t),$$

where w_{it} is the budget share of the ith good in period t, t is a linear time trend, p_{jt} is the price of the jth good, X_t is total expenditure on all the goods in the system and $\ln P_t$ is a price index, here approximated by a Stone price index, $\ln P_t = \sum_i w_{it} \ln p_{it}$, to keep the demand equations linear.

[7] Several issues regarding the specification of the system, as derived demand, weak separability and simultaneity need a discussion. As these issues appears in a parallel fashion in Chapter 5, I refer to the discussion there.

To be in accordance with economic theory, the parameters of the demand equations must satisfy the following restrictions;

Adding up: $\sum_i \alpha_i = 1,\ \sum_i \alpha_{iT} = 0,\ \sum_i \gamma_{ij} = 0,\ \sum_i \beta_i = 0,$

Homogeneity: $\sum_j \gamma_{ij} = 0$ and

Symmetry: $\gamma_{ij} = \gamma_{ji},\ i \neq j.$

The adding up condition is satisfied by the construction of the data, while the homogeneity and symmetry restriction must be imposed on the estimated parameters.[8] As the budget shares sum to unity the covariance matrix of the demand system is singular. To avoid this problem one equation must be deleted. The system is invariant to which equation is deleted and the parameters of the deleted equation may be retrieved using the adding up conditions (Barten, 1969).

As the data series are nonstationary, before we proceed we must confirm that they are cointegrated, i.e., form a long-run relationship, to avoid spurious regression problems (Engle and Granger, 1987). This is done as suggested by Engle and Granger by testing the residuals from the demand system for stationarity using the Augmented Dickey-Fuller test. The null hypothesis of a unit root corresponds to no cointegration, i.e., no long-run relationship. The results from these tests are presented in Table 4.2. As the null hypothesis of a unit root is rejected at a 10% significance level for all equations, we may conclude that the data series in all the demand relationships are cointegrated.

[8] Note that the homogeneity restriction is redundant, as no money illusion is already imposed since real prices are used. However, the results do not change when using nominal prices when the homogeneity and symmetry restrictions are imposed. As the redundant restriction is used in Asche (1996), the results are reported in this fashion also here.

Table 4.2. Cointegration tests

Tested Equation	Fresh salmon	Frozen salmon	Smoked salmon
Test Statistic	-4.351	-5.048	-6.284

Critical value is -4.415 at a 5% level and -4.186 at a 10% level (MacKinnon, 1991).

4.3 The Fully Modified Least Squares Estimator

Normal inference is in general not valid when the data series are nonstationary, even if they are cointegrated. The advantage with the Fully Modified Least Square (FMLS) estimator (Phillips and Hansen, 1990), is that it removes the nonstandard elements in the estimated parameters' distributions, yielding estimators where normal inference theory applies. Also, as an autocorrelation consistent estimate of the covariance matrix is used in the FMLS estimator, the FMLS estimator will be robust against short-run dynamics causing autocorrelation.

To discuss the FMLS estimator (Phillips and Hansen, 1990), it is convenient to start with Phillip's triangular error correction system (Phillips, 1991), but with Hansen's (1992) modifications to include deterministic components. Let y_t be a n-vector $I(1)$ process,[9] u_t be a n-vector stationary time series whose long-run covariance matrix is nonsingular and z_t a vector including a constant term and other possible deterministic components such as a time trend.[10] We partition these vectors into subvectors of dimension n_1 and n_2 with $n=n_1+n_2$ and assume that the data generating mechanism for y_t is the cointegrated system;

(2) $$y_{1t} = A_1 z_{1t} + By_{2t} + u_{1t} = Cx_t + u_{1t},$$

[9] A data series is said to be integrated of order one or $I(1)$, if it needs to be differenced once to become stationary.

[10] Note that the vectors of deterministic components in (2) and (3) must not necessarily contain the same components. The introduction of these vectors of deterministic components is the modification of Hansen (1992) compared to Phillips and Hansen (1990).

(3) $\Delta y_{2t} = A_2 z_{2t} + u_{2t}$.

Here B is an $n_1 \times n_2$ matrix of coefficients which together with the coefficients in A_1 give the long-run parameters in the system, $C = [A_1\ B]$, and u_{1t} might be thought of as representing stationary deviations from equilibrium. The coefficients in A_2 give deterministic components such as a drift in the random walks in (3). In the case with the almost ideal demand system, the vector y_{1t} corresponds to the budget shares, z_{1t} to the constant term and the trend and the vector y_{2t} to the prices and the expenditure variable. Let the innovations in (2) and (3), u_t, satisfy the invariance principle

(4) $$T^{-1/2}\sum_{1}^{[Tr]} u_t \Rightarrow S(r) \equiv BM(\Omega),$$

where $BM(\Omega)$ is a vector Brownian motion with covariance matrix Ω. This will be true if u_t is $iid(0,\Omega)$ or a strictly stationary and ergodic sequence of martingale differences with conditional variance matrix Ω. We partition conformably with y the covariance matrix Ω, that is,

$$\Omega = \begin{bmatrix} \Omega_{11} & \Omega_{12} \\ \Omega_{21} & \Omega_{22} \end{bmatrix} = \Sigma + \Theta + \Theta',$$

where Σ is the contemporaneous correlation, and the limit process S as $S' = (S_1', S_2')$ and defines $\Omega_{11\cdot2} = \Omega_{11} - \Omega_{12}\Omega_{22}^{-1}\Omega_{21}$ and the component process $S_{1\cdot2} = S_1 - \Omega_{12}\Omega_{22}^{-1}S_2 \equiv BM(\Omega_{11\cdot2})$ which is independent of S_2.

Phillips (1991) shows that the OLS estimator of B in the system given by (2) generally is distributed as:

(5) $$T(\hat{B} - B) \Rightarrow \left(A\int_0^1 dSS_2'\right)\left(\int_0^1 S_2S_2'\right)^{-1} \equiv \left(\int_0^1 dS_{1\cdot2}S_2'\right)\left(\int_0^1 S_2S_2'\right)^{-1}$$
$$+\Omega_{12}\Omega_{22}^{-1}\left(\int_0^1 dS_2S_2'\right)\left(\int_0^1 S_2S_2'\right)^{-1}.$$

In general, the limit distribution in (5) is a linear combination of the "unit root" distribution given by $\left(\int_0^1 dS_2S_2'\right)\left(\int_0^1 S_2S_2'\right)^{-1}$ and the compound normal distribution $\left(\int_0^1 dS_{1\cdot2}S_2'\right)\left(\int_0^1 S_2S_2'\right)^{-1}$. Similar results are shown by Chambers (1993) in the case when restrictions are imposed on B. Only if Ω_{12}=0, i.e., y_{2t} is strictly exogenous, the presence of the "unit root" distribution in (5) disappears, and (5) reduces to a normal distribution. In this case, Ordinary Least Squares (OLS) estimation of (2) is equivalent to Maximum Likelihood Estimation of (2) and (3) if B is unrestricted. If B is restricted, as it is in an almost ideal demand system, the Seemingly Unrelated Regression estimator (SUR) is necessary to obtain Maximum Likelihood Estimates.

The FMLS estimator of Phillips and Hansen (1990) is constructed to correct for the endogeneity problem (i.e., the unit root element in (5)) which is created if y_{2t} is not strictly exogenous. This is important as it gives estimators with standard distributions such that ordinary inference theory may be applied. The FMLS estimator with Hansen's modification is given as:

$$(6) \qquad \hat{B} = \left(x_t'x_t\right)^{-1}\left(x_t'y_{1t}^{+} - T\begin{bmatrix} 0 \\ \hat{d} \end{bmatrix}\right),$$

where the dimension of the 0-vector is equal to the number of deterministic components in (2),

$$y_{1t}^{+} = y_{1t} - \hat{\Omega}_{21}\hat{\Omega}_{22}^{-1}\Delta y_{2t} \text{ and}$$
$$\hat{d} = \text{vec}(\hat{\Lambda}_{21}) - (I_{n1} \otimes \hat{\Omega}_{21}\hat{\Omega}_{22}^{-1})\text{vec}(\hat{\Lambda}_{22}),$$

and where $\hat{\Omega}_{kl}$ and $\hat{\Lambda}_{kl}$ are consistent estimates of the appropriate submatrices of the covariance matrix Ω and $\Lambda = \Sigma + \Theta$. It is clearly seen that if $\Omega_{21}=0$, the FMLS estimator collapses to an OLS estimator or SUR estimator depending on whether there are cross equation restrictions or not. Hence, the FMLS estimator will correct the problem with unit root elements in the distributions of the estimators if it exists, and leave the estimators unaltered otherwise.

Phillips and Hansen (1990) used Newey and West's (1987) estimator to obtain a consistent estimator for the long-run covariance matrix. This estimator may be written as

(7) $\hat{\Omega} = \frac{1}{T} \sum_{v=-T+1}^{T-1} k\left(\frac{j}{W_T}\right) \sum \hat{u}_{t-j} \hat{u}_t'$,

where $k\left(\frac{j}{W_T}\right)$ is a kernel estimator and W_T is the bandwidth parameter. Newey and West based the kernel in their covariance estimator on a Bartlett kernel. However, Andrews (1991) found this kernel to be inferior to several others, of which a quadratic spectral kernel was found to be superior. Both Hansen (1992) and Chambers (1993) consider this kernel and it will be used also here. The kernel is given as

(8) $k(x) = \left[\frac{25}{12\pi^2 x^2}\right] \left[\frac{\sin\left(\frac{6\pi x}{5}\right)}{\frac{6\pi x}{5}} - \cos\left(\frac{6\pi x}{5}\right)\right], \quad x = \frac{j}{W_T}$.

Originally, there were no formal guidelines for choosing the size of the bandwidth parameter. It was only noted that it must be chosen large enough to control for possible autocorrelation (Newey and West, 1987). However, Andrews (1991) also suggested an automatic selection procedure for the bandwidth parameter. This requires the residuals from the system given by (2) and (3) to be modelled as either n AR(p) models or one VAR(p) model. The lag length must be selected sufficiently large to control for autocorrelation. In our case, p=1 is sufficient. Let ρ_i and σ_i respectively denote the estimated autoregressive parameter and the error standard deviation from the ith equation in the system given by (2) and (3). The scalar $\hat{\alpha}$ may then be estimated as

(9) $\hat{\alpha} = 4\sum_{i=1}^{n} \frac{\hat{\rho}_i^2 \hat{\sigma}_i^4}{(1-\hat{\rho}_i)^8} \Big/ \sum_{i=1}^{n} \frac{\hat{\sigma}_i^4}{(1-\hat{\rho}_i)^4}$.

The bandwidth parameter is then given as (Andrews, 1991):

(10) $\hat{W}_T = 1.3221[T\hat{\alpha}]^{1/5}$.

The bandwith parameter was in our case found to be W_T=1.88.

Note that it is the long-run covariance matrix we obtain an estimate for, and problems caused by short-run dynamics such as autocorrelation are thereby avoided. Therefore, this estimator is known in the literature as a heteroscedasticity and autocorrelation consistent (HAC) covariance matrix estimator. The FMLS estimator accordingly corrects both for nonstandard distributions caused by unit roots and autocorrelation. Note from (5) and (7) that if there is no heteroscedasticity or autocorrelation and no problems with unit root distributions in (2) and (3), OLS or SUR estimation on (2) are equal to the FMLS estimates depending on whether there are cross equation restrictions or not.

4.4 Empirical Results

There is a substantial literature on the demand for salmon using time series data (DeVoretz, 1982; Kabir and Ridler, 1982; Bird, 1986; Herrmann and Lin, 1988; Bjørndal, Salvanes and Andreassen 1992; Bjørndal, Gordon and Singh, 1993; DeVoretz and Salvanes, 1993; Herrmann, Mittelhammer and Lin, 1993; Wessells and Wilen, 1993; 1994). However, in this literature only the demand for fresh salmon or an aggregate of salmon is modeled, although demand is sometimes divided into different subspecies of salmon such as Atlantic and Pacific salmon (e.g. Herrmann and Lin (1988)).[11] Frozen salmon is the only other product form of salmon that is at times considered, as it is sometimes used as, and found to be a substitute for fresh salmon.[12] Fresh salmon or aggregate salmon are mostly found to be strongly own-price elastic, and a luxury good (i.e., income elastic). However, with exception of Kabir and Ridler (1984), the demand for frozen and smoked salmon, and the relationships between these goods have not been modeled earlier to the author's knowledge.

The data series were found to be nonstationary but cointegrated. Also, the presence of autocorrelation suggest omitted dynamics. Hence, the almost ideal demand system in (1) was reestimated with the FMLS estimator. To avoid a singular covariance matrix, the demand system was estimated without the equation for smoked salmon. The

[11] Wessells and Wilen (1993; 1994) use two product forms of salmon, an aggregate of fresh and frozen salmon and salted salmon.
[12] Kabir and Ridler (1984) also estimate the demand for wild-caught frozen Atlantic salmon.

parameter estimates are presented in Table 4.3, and with one exception all parameter estimates are significantly different from zero, at least at a 10% significance level.[13] Uncompensated price elasticities and expenditure elasticities are presented in Table 4.4, and compensated price elasticities are presented in Table 4.5.[14]

The results are in line with what is usually found in the literature where comparable results exist. Both the uncompensated and compensated own-price elasticity for fresh salmon are elastic, and the uncompensated elasticity is also significantly larger than one. However, the magnitude of the elasticities is lower than what is usually found. This gives some support to the results of Bjørndal, Salvanes and Andreassen (1992), who found the own-price elasticity of a salmon aggregate to be barely elastic (-1.3). The explanation for the low own-price elasticities may be that both the study of Bjørndal, Salvanes and Andreassen (1992) with a data set containing observations through June 1990, and this study with a data set with as recent observations as the last quarter of 1992, capture the impact of increased salmon consumption in Europe during the late 1980s which the earlier studies are not able to capture (see also Figure 5.1). The own-price elasticities are inelastic for both frozen and smoked salmon, and both elasticities are not significantly different from zero for frozen salmon. Only the uncompensated elasticity is significantly different from zero for smoked salmon. This is reasonable, although there are no comparable results in the literature.

---

[13] It must be noted that the homogeneity and symmetry restrictions that are imposed on the parameter estimates, are rejected by the data. It should be noted that nominal prices were used in these tests.
[14] The elasticities are computed by the formula that Green and Alston (1990) denote as group (iii).

Table 4.3. Parameter estimates

Equation:	Fresh Salmon		Frozen Salmon	
Variable	Parameter	St. Dev.	Parameter	St.Dev.
Constant	-1.1747*	(0.4704)	4.0851*	(0.5554)
Trend	0.0022	(0.0014)	0.0048*	(0.0016)
Fresh price	-0.2196*	(0.0821)	0.1025**	(0.0628)
Frozen price	0.1025**	(0.0628)	0.1545*	(0.0939)
Smoked price	0.1171*	(0.0564)	-0.2570*	(0.0731)
Expenditure	0.1315*	(0.0493)	-0.3365*	(0.0579)

*indicates significant at a 5% level and ** indicate significant at a 10% level.

Table 4.4. Uncompensated elasticities[a,b]

	Fresh	Frozen	Smoked	Expenditure
Fresh	-1.725*	0.135	0.235**	1.355*
	(0.2429)	(0.1989)	(0.1695)	(0.1331)
Frozen	0.567*	-0.277	-0.449*	0.158*
	(0.1498)	(0.2301)	(0.1771)	(0.1449)
Smoked	0.197	-1.491*	-0.596*	1.891*
	(0.3382)	(0.3213)	(0.2547)	(0.1005)

* indicates significant at a 5% level and ** indicates significant at a 10% level.

[a] Standard deviations are in parentheses.

[b] $\eta_{ij} = \frac{\gamma_{ij}}{w_i} - \beta_i \frac{w_j}{w_i} - \delta, \ \delta = 1 \text{ for } i = j, \delta = 0 \text{ for } i \neq j.$

Table 4.5. Compensated elasticities[a,b]

	Fresh	Frozen	Smoked	Expenditure
Fresh	-1.223*	0.677*	0.546*	1.355*
	(0.2220)	(0.1698)	(0.2454)	(0.1331)
Frozen	0.626*	-0.232	-0.413*	0.158
	(0.1571)	(0.2347)	(0.1828)	(0.1449)
Smoked	0.879*	-0.717*	-0.161	1.891*
	(0.2454)	(0.3179)	(0.1823)	(0.1005)

* indicates significant at a 5% level and ** indicates significant at a 10% level.

[a] Standard deviations are in parentheses.

[b] $\eta_{ij}^{*} = \frac{\gamma_{ij}}{w_i} + w_j - \delta,\ \ \delta = 1 \text{ for } i = j, \delta = 0 \text{ for } i \neq j.$

As expected, frozen and smoked salmon both appear to be substitutes for fresh salmon. The compensated cross-price elasticities are all significantly different from zero, while the uncompensated elasticity for fresh salmon in the equation for frozen salmon is the only one of these uncompensated cross-price elasticities significantly different from zero. Frozen and smoked salmon are strong complements, and all these cross-price elasticities are significantly different from zero. This result is a little surprising, but it seems reasonable when the fact that frozen salmon is used mostly as an input factor in the European smoking industry is taken into consideration. It should here also be noted that smoked salmon mostly is imported as a specialty, as the EU import levy is substantially higher on smoked (13%) than on frozen (2%) salmon, and that the imported quantity of frozen salmon is more than seven times as high as the import of smoked salmon in the period covered by our data set. This also implies that the levy is effective as it gives little scope for processing outside the EU. Both fresh and smoked salmon appear to be luxury goods, as both expenditure elasticities are significantly larger than one, while frozen salmon is expenditure inelastic.

4.5 Concluding Remarks

A demand system for fresh, frozen and smoked salmon was estimated with the almost ideal demand system of Deaton and Muellbauer (1980b). As budget shares, prices and expenditure in the system were found to be nonstationary but cointegrated, normal SUR estimation of the demand system might not be appropriate. However, the problems this might have created, together with possible dynamics, were avoided by using the Fully Modified Least Squares (FMLS) estimator of Phillips and Hansen (1990). The empirical results were reasonable, and gave new information about the demand for frozen and smoked salmon. Both fresh and smoked salmon were found to be luxury goods, and while both fresh and frozen and fresh and smoked salmon were substitutes, frozen and smoked salmon are complements. The results also support Bjørndal, Salvanes and Andreassen (1992) in that all categories of salmon are found to be less own-price elastic than in many of the other earlier studies. It may therefore seem as if the great increase in salmon consumption in the late 1980s and the introduction of salmon into new markets such as fast food restaurants and supermarkets might have caused the demand for salmon to become less elastic.

REFERENCES

Andrews, D. W. K. (1991) "Heteroskedasticity and Autocorrelation Consistent Covariance Matrix Estimation," *Econometrica,* 59, 817-858.

Asche, F. (1996) "A System Approach to the Demand for Salmon in the European Union," *Applied Economics*, 28, 97-101.

Barten, A. P. (1969) "Maximum Likelihood Estimation of a Complete System of Demand Equations," *European Economic Review,* 1, 7-73.

Bird, P. (1986) "Econometric Estimation of World Salmon Demand," *Marine Resource Economics,* 3, 169-182.

Bjørndal, T., D. V. Gordon, and B. Singh (1993) "A Dominant Firm Model of Price Determination in the US Fresh Salmon Market: 1985-1988," *Applied Economics,* 25, 743-750.

Bjørndal, T., K. G. Salvanes, and J. H. Andreassen (1992) "The Demand for Salmon in France: the Effects of Marketing and Structural Change," *Applied Economics,* 24, 1027-1034.

Chambers, M. J. (1993) "Consumers' Demand in the Long Run: Some Evidence from UK Data," *Applied Economics,* 25, 727-733.

Deaton, A. S. and J. Muellbauer (1980a) "An Almost Ideal Demand System," *American Economic Review,* 70, 312-326.

Deaton, A. S. and J. Muellbauer (1980b) *Economics and Consumer Behavior*, New York: Cambridge University Press.

DeVoretz, D. (1982) "An Econometric Demand Model for Canadian Salmon," *Canadian Journal of Agricultural Economics,* 30, 49-60.

DeVoretz, D. J. and K. G. Salvanes (1993) "Market Structure for Farmed Salmon," *American Journal of Agricultural Economics,* 75, 227-233.

Dickey, D. A. and W. A. Fuller (1979) "Distribution of the Estimators for Autoregressive Time Series with Unit Root," *Journal of the American Statistical Association,* 74, 427-431.

Dickey, D. A. and W. A. Fuller (1981) "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root," *Econometrica,* 49, 1057-1072.

Engle, R. F. and C. W. J. Granger (1987) "Co-integration and Error Correction: Representation, Estimation and Testing," *Econometrica,* 55(2), 251-276.

Fuller, W. A. (1976) *Introduction to Statistical Time Series Models*, N.Y: J. Wiley & Sons.

Green, R. and J. M. Alston (1990) "Elasticities in AIDS models," *American Journal of Agricultural Economics*, 72, 442-445.

Hansen, B. E. (1992) "Efficient Estimation and Testing of Cointegration Vectors in the Presence of Deterministic Trends," *Journal of Econometrics,* 53, 87-121.

Herrmann, M. L. and B. H. Lin (1988) "The Demand and Supply of Norwegian Atlantic Salmon in the United States and the European Community," *Canadian Journal of Agricultural Economics,* 38, 459-471.

Herrmann, M. L., R. C. Mittelhammer, and B. H. Lin (1993) "Import Demand for Norwegian Farmed Atlantic Salmon and Wild Pacific Salmon in North America, Japan and the EC," *Canadian Journal of Agricultural Economics,* 41, 111-125.

Jorgenson, D. W. (1964) "Minimum Variance, Linear, Unbiased Seasonal Adjustment in Economic Time Series," *Journal of the American Statistical Association,* 59, 681-725.

Kabir, M. and N. B. Ridler (1984) "The Demand for Atlantic Salmon in Canada," *Canadian Journal of Agricultural Economics*, 32, 560-568.

MacKinnon, J. G. (1991) "Critical Values for Co-Integration Tests," In *Long-Run Economic Relationships*, ed. R. F. Engle and C. W. J. Granger. 267-276. Oxford: Oxford University Press.

Newey, W. K. and K. D. West (1987) "A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix," *Econometrica,* 55, 703-708.

Phillips, P. C. B. (1986) "Understanding Spurious Regressions in Econometrics," *Journal of Econometrics,* 33, 311-340.

Phillips, P. C. B. (1991) "Optimal Inference in Cointegrated Systems," *Econometrica,* 59, 283-306.

Phillips, P. C. B. and B. E. Hansen (1990) "Statistical Inference in Instrumental Variables Regressions with I(1) Processes," *Review of Economic Studies,* 57, 99-125.

Salvanes, K. G. and D. J. DeVoretz (1993) "Household Demand for Fish and Meat Products: Separability and Demographic Effects," *Preliminary Version.*

Wessells, C. R. and J. E. Wilen (1993) "Economic Analysis of Japanese Household Demand for Salmon," *Journal of the World Aquaculture Society,* 24, 361-378.

Wessells, C. R. and J. E. Wilen (1994) "Seasonal Patterns and Regional Preferences in Japanese Household Demand for Seafood," *Canadian Journal of Agricultural Economics,* 42, 87-103.

White, K. J. (1978) "A General Computer Program for Econometric Methods-SHAZAM," *Econometrica,* 46, 239-240.

5: A LINEAR DYNAMIC DEMAND SYSTEM: THE DEMAND FOR SALMON IN THE EUROPEAN UNION

5.1 Introduction

The most general specification used in the literature to model dynamics in demand systems is the error correction representation suggested by Anderson and Blundell (1982; 1983; 1984). In Anderson and Blundell's framework, the demand relationships are specified with the almost ideal demand system (AIDS) of Deaton and Muellbauer (1980a). A dynamic specification is obtained by adding lagged variables to the model to account for the dynamics. This gives the demand system the form of an autoregressive distributed lag model, which subsequently is transformed into an error correction representation. This framework has been applied in a number of studies and results indicate that a sufficiently rich dynamic specification is important when modelling demand relationships (Anderson and Blundell, 1983; 1984; Veall and Zimmermann, 1986).[1] In particular, a correct dynamic specification provides valid inference as autocorrelation is avoided. Also, the homogeneity and symmetry restrictions implied by economic theory have not been rejected in any of these specifications where the dynamics in the system are controlled for. This is in contrast to many empirical studies using static demand specifications, where such regularity

[1] The framework has been used more extensively on the producer side, by specifying factor demand functions derived from a translog production or cost function (see e.g. Anderson and Blundell, 1982).

conditions generally fail (for a brief review, see Deaton and Muellbauer, 1980b, ch. 3).

A potential difficulty with Anderson and Blundell's specification in applied work is that the equation system to be estimated is nonlinear. In addition to being computationally expensive, problems can arise in nonlinear regression because the parameter estimates may be sensitive to the starting values for the parameters, as the criterion function may have several local optima (see Davidson and MacKinnon, 1993, p. 44).[2] Moreover, because the criterion function may have several local optima, one is never sure, even when different sets of starting values are used, of obtaining the global optimum. In this paper the Bewley transformation as advocated by Wickens and Breusch (1988) is used to obtain a linear specification of the demand equations. The above mentioned problems may then be avoided, as this linear specification gives a criterion function with a unique optimum.

Berndt and Savin (1975) show that when an autoregressive structure is present in a singular system of equations, cross equation autocorrelation is also likely, as the autoregressive structure becomes very restrictive if cross equation autocorrelation is not allowed for. If cross equation autocorrelation is present but ignored, the autoregression parameters in each equation must be equal. As the most common functional forms for demand systems are singular both on the factor side and on the consumer side (e.g. the translog, the almost ideal and the Rotterdam systems), a test

---

[2] Whether the criterion function is maximised or minimised depends on the estimation technique, i.e., whether maximum likelihood, least squares, IV or GMM is used.

for serial correlation in these specifications should also specify cross equation serial correlation as a part of the alternative hypothesis. In applied work using demand system specifications, a Durbin-Watson test is common when any test against dynamic misspecification is reported. However, as the Durbin-Watson test does not account for cross equation autocorrelation under the alternative, it may be a weak test in connection with demand systems. In Section 5.2, we suggest to use the LM test of Godfrey (1981) in a system of demand equations. Although Godfrey applied the LM test to a simultaneous equation system, the test is also appropriate for a system of demand equations as the test allows for cross equation autocorrelation to be specified as a part of the alternative. As well, the LM test is a test for serial correlation in the system, not equation by equation like the Durbin-Watson test. In singular systems, the LM test is invariant to which equation is deleted.

The linear approach to a dynamic specification of a system of demand equations will be used to estimate the demand equations for three product categories of salmon (fresh, frozen and smoked) in the European Union using quarterly data for the period 1981-1992. The demand for fresh salmon and an aggregate category of all salmon has been studied extensively using time series data (DeVoretz, 1982; Kabir and Ridler, 1984; Bird, 1986; Herrmann and Lin, 1988; Bjørndal, 1990; Bjørndal, Salvanes and Andreassen, 1992; DeVoretz and Salvanes, 1993; Herrmann, Mittelhammer and Lin, 1993; Wessells and Wilen, 1993, 1994; Bjørndal, Gordon and Salvanes, 1994 and Chapter 4 in this dissertation).[3] With the exception of Wessells and Wilen (1993;

[3] It should be noted that the demand functions in Herrmann and Lin (1988) and Herrmann *et al.* (1993) are parts of a larger equilibrium model. However, each demand function is specified with a single equation and does not allow imposition of adding up, homogeneity and symmetry restrictions.

1994) and Chapter 4, a common feature of all these studies is the use of a single equation approach to the specification of the demand function.[4] Cross-equation interactions between the demand functions such as symmetry have been ignored together with most dynamic characteristics. Also, single equation demand functions will be in accordance with economic theory only under restrictive assumptions (Deaton and Muellbauer, 1980b, ch. 3).[5] A system approach to the demand analysis allows the adding up condition to be imposed and the homogeneity and symmetry restrictions implied by economic theory to be tested or imposed.[6] Hence, one can ensure that the estimated demand system is in accordance with economic theory.

As indicated above, dynamic specifications are important to obtain valid inference when using time series data, and also to obtain specifications in accordance with economic theory. There are of course several reasons for including dynamics, both econometric, such as dependencies over time in the data series, and economic (see e.g. Pollak, 1970), such as habit formation, contractual obligation and imperfect information that cause adjustment costs which may delay the adjustment toward long-run equilibrium. Several of these issues may be important in this study. Dependencies over time in our data series are likely, as in all time series. Moreover, the market for salmon in the European Union has gone through important changes during the last 10-15 years due to the introduction of farmed salmon. This may indicate that the demand for salmon periodically has departed from long-run equilibrium. This study deviates

[4] Wessells and Wilen (1993; 1994) estimate a Japanese demand system for several seafood products including fresh and salted salmon, while in Chapter 4 the demand for fresh, frozen and smoked salmon in the European Union is estimated.

[5] For instance, the budget or adding up restriction will hold only if demand is homothetic.

[6] The system approach also leads to more efficient parameter estimation, as more information is utilised.

from Wessells and Wilen (1993; 1994) and Chapter 4 in using a more general dynamic structure, as autoregressive errors are assumed in these studies.

The empirical results obtained in this study may also be of interest, as the above mentioned studies, with the exception of Chapter 4, do not provide any information about smoked salmon, and little information about frozen. Knowledge of the demand for frozen and smoked salmon and the relationships between the three commodities is accordingly limited.

This chapter is organised as follows. In the next section, an LM test is suggested for demand system specifications. In Section 5.3, the data set and the almost ideal demand system are described. In Section 5.4, the dynamic framework and the relation between the linear specification used in this paper and the error correction specification of Anderson and Blundell is discussed. The empirical results are reported in Section 5.5, before concluding remarks are given in Section 5.6.

5.2 Serial Correlation

Consider the following multivariate linear regression model

(1) $y_t = \Pi x_t + v_t$,

where y_t is an $n\times 1$ vector of dependent variables, Π is an $n\times k$ matrix of unknown parameters, x_t is aN $k\times 1$ vector of exogenous variables and v_t is an $n\times 1$ vector of random disturbances. When using time series data, it is well known that in equation systems where the errors are contemporarily correlated across the equations, serial correlation may also be present across the equations (Guilkey and Schmidt, 1973).

This problem persists also in singular equation systems (Berndt and Savin, 1975). The problem considered by Guilkey and Schmidt (1973) and Berndt and Savin (1975) is when v_t is generated by the stationary vector stochastic process

(2) $v_t = Rv_{t-1} + e_t$,

where

$$E(e_{i,t}) = 0$$
$$E(e_{i,t}e_{j,s}) = \begin{cases} \sigma_{ij} & \text{for } t = s \\ 0 & \text{for } t \neq s \end{cases}$$

and R is an $n \times n$ matrix of unknown parameters. In singular systems, the adding up condition implies that $i'R=k'$, where i is a vector of ones (Berndt and Savin, 1975), such that all the nonzero parameters in R must be equal if R is diagonal. Also, note that if R=0, (1) reduces to a conventional system of seemingly unrelated regressions.

The possibility that R may not be diagonal is not reflected in the tests for serial correlation or dynamic misspecification in demand systems used in the literature. When testing for serial correlation, it is common to test for autocorrelation within each equation using a Durbin-Watson test, and less frequently a Box-Pierce or Ljung-Box tests. A weakness with these tests is that they ignore the possibility of cross equation autocorrelation under the alternative hypothesis, and the tests may accordingly have low power in cases where cross equation autocorrelation is present. Godfrey (1981) introduced in a simultaneous equation context a LM test which also allows cross equation serial correlation to be specified under the alternative hypothesis. This LM test can be used also in the seemingly unrelated regression case. This is of particular importance in singular equation systems, as the assumption of a diagonal autoregressive structure implies the strict (and unlikely) restriction that the autocorrelation parameter is the same in all equations.

To avoid the singularity problem, one equation is deleted before estimation in singular equation systems. In a system with autoregressive errors the singularity problem also introduces a redundant variable problem when *R* is not diagonal. This is solved by Berndt and Savin by subtracting the last column from the other columns in *R* when one equation is deleted. In the rest of this section it is assumed that one equation is deleted from the system and the necessary transformation of *R* has been undertaken in (1) and (2) in the case of singular equation systems such that both singular and non-singular systems will be treated at the same time.

An LM test for serial correlation is undertaken by first regressing the static system in (1) obtaining the disturbance vector v_t^s. Then, respecify the equations to include the lagged values of the disturbance vector or;

(3) $y_t = \Pi x_t + S v_{t-1}^s + e_t^*, \qquad e_t^* \sim \text{nid}(0,\Omega).$

where *S* is a $n \times n$ matrix. The null hypothesis of no autocorrelation is then tested by testing the hypothesis that $H_0{:}S=0$. This can be done both by a likelihood ratio test using (1) and (3) or by a Wald test using (3). The test statistic is distributed as χ^2 with n^2 degrees of freedom. The test generalises easily to cases with higher order serial correlation by including higher lags of the residuals from the static regression in (3).

There are several advantages with the LM test compared to either Durbin-Watson or Ljung-Box tests in an equation system. As autoregressive and moving average errors are locally equivalent alternatives in the LM test, the LM test also provides a test for moving average errors (Godfrey, 1981). Moreover, it is a test for serial correlation in the system, not equation by equation. This may be of particular importance in singular systems.

Theorem 1: In singular equation systems, the LM test is invariant to which equation is deleted.

This is most straightforward to see using the likelihood ratio test to test for serial correlation. Barten (1969) shows that the likelihood function is invariant to which equation is deleted. It is then straightforward to see that any likelihood ratio test, including the LM test for serial correlation is invariant to which equation is deleted.

That the LM test is a test for serial correlation in the system together with the invariance property may be useful in applied work. As the Durbin-Watson and Ljung-Box tests test for serial correlation equation by equation, one might find evidence for serial correlation in some equations, while not in others. It is then not necessarily straightforward what to do. This problem is avoided when using the LM test, as this is a test for serial correlation in the system. In singular systems where serial correlation is present in only one equation, the invariance property of the LM test ensures that it is not possible to "hide" this by deleting this equation. This is in contrast to approaches using the Durbin-Watson or Ljung-Box test, which is not invariant to which equation is deleted because of their equation by equation approach.

One may of course also test against more limited alternatives using the LM test. For example a test against the alternative hypothesis that R is diagonal may be tested by restricting S to be diagonal.

5.3 Data and Specification

We will estimate the demand equations for three different product categories of salmon utilising the almost ideal demand system of Deaton and Muellbauer (1980a). The data set consists of import data from the European Union's trade statistics, Eurostat, and was made available for this study by the Norwegian Seafood Export Council in Tromsø (see also Chapter 3.7). The data set contains deseasonalised data series on value and quantity of quarterly imports into the European Union of fresh, frozen and smoked salmon for the period 1981(1)-1992(4).[7] The deseasonalisation of the data series is done by removing deterministic seasonality with quarterly dummy variables, as described by Jorgensen (1964).

Each equation in the almost ideal demand system is given by

$$w_{it} = \alpha_i + \alpha_{iT} t + \sum_j \gamma_{ij} \ln p_{jt} + \beta_i \ln(X_t / P_t), \tag{4}$$

where w_{it} denotes the share of the ith good, t a linear time trend, $\ln p_{jt}$ the price of the jth good, $\ln X_t$ the expenditure on the n goods in the system and $\ln P_t$ a price index. The price index is a translog index,

[7] This leaves a slight bias in the data set as national consumption is not included for the producing countries inside the Union. Inside the European Union, only the UK has a significant production of salmon, and as UK's consumption of salmon is small compared to the total demand in the European Union, the error this introduces in the data is probably small.

(5) $$\ln P_t = \alpha_0 + \sum_i \alpha_i \ln p_{it} + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln p_i \ln p_j .$$

The translog price index makes the demand system nonlinear. To avoid nonlinearity, Deaton and Muellbauer suggested that the price index could be approximated by a Stone price index, i.e., $\ln P_t = \sum_i w_{it} \ln p_{it}$. Recently, the use of the Stone price index has been shown to be inappropriate as it causes the estimated parameters to be inconsistent (Pashardes, 1993; Buse, 1994; Moschini, 1995), see also the discussion in Chapter 2. Moschini attributes this problem to the fact that the Stone price index does not satisfy what Diewert calls the commensurability property, and suggests that the problem may be solved by using a price index that satisfy this property.[8] Moschini suggests several other price indices that satisfy this property and may be used to keep the specification of the almost ideal demand system linear. He also shows that these indices perform as well as the translog index.

To keep the specification of the demand system linear, we will here use what Moschini calls the corrected Stone index, which may be written as[9]

(6) $$\ln P_t = \sum_i w_{it} \ln\left(\frac{p_{it}}{p_i^0}\right)$$

Economic theory implies the following restrictions on the equation system:

adding up: $\sum_i \alpha_i = 1,\ \sum_i \alpha_{iT} = 0,\ \sum_i \gamma_{ij} = 0,\ \sum_i \beta_i = 0,$

homogeneity: $\sum_j \gamma_{ij} = 0$, and

[8] The commensurability property means that a price index should be invariant to the units of measurement of prices.

[9] Note that the Stone price index is identical to the corrected Stone index if the prices are normalised to unity before the price index is computed.

symmetry: $\gamma_{ij} = \gamma_{ji}$, $i \neq j$.

The adding up conditions, which are automatically satisfied by the data, imply that the covariance matrix is singular. This problem can be avoided by deleting one equation from the system. The system is invariant to which equation is deleted, and the parameters in the deleted equation may be retrieved using the adding up conditions.

By limiting the analysis to three product forms of salmon, we implicitly assume weak separability between these three goods and all other goods in the consumer's bundle. This might seem a strict assumption. However, market delineation studies indicate that the assumption is not very restrictive. In particular, Gordon, Salvanes and Atkins (1993) conclude that salmon does not compete in the same market segment as turbot and cod. As this also implies that salmon does not compete in the same market segment as other species that belong to the same segment as turbot and cod, it should not be too unreasonable to assume weak separability between salmon and different types of white fish. There might still be a potential problem with other high-valued seafood products. However, as their budget shares are generally very low, the impact of omitting them should not be large, even if they indeed belong to the same market segment as salmon.

Some additional specification problems are worth discussing.[10] The fact that we are using import data might have implications for the interpretation of the results. The almost ideal demand system is a consumer demand model, while the fact that we are using import data might imply that a derived demand system is estimated. This might

[10] For a more thorough discussion of the problems of simultaneity and derived demand, see Chapter 2.

cause problems as consumer preferences are not necessarily reflected by the intermediaries' demand. Both the market structure and the intermediaries' production technology may cause the derived demand functions to deviate from the consumer's demand functions.

The intermediaries' production technology may cause their demand for a commodity to differ from consumer demand, since the producers have substitution possibilities in response to changes in the relative prices of input factors (Gardner, 1975; Wohlgenant, 1989). However, in our case, each imported good is the main factor in the intermediaries' production processes. It therefore seems reasonable to treat each of the goods as the only variable factor in the respective intermediaries' optimisation problems.[11] In this case, the intermediate demand elasticities will equal the consumer demand elasticities, and the intermediaries' demand will mirror the consumers' demand. See also the discussion of derived demand in Chapter 2.8 and Figure 2.1.

The market structure can cause import demand to deviate from consumer demand if the intermediaries have market power or if there is a significant domestic production. If the intermediaries have market power, they will drive a wedge between the consumers' demand and the derived demand to extract the monopolistic profit. This will be true both if the intermediaries have market power in the retail markets (oligopoly) or in the input factor markets (oligopsony), see Goodwin (1994). For the three salmon categories, it seems unlikely that any intermediaries have market power,

[11] As some amounts of other factors obviously are needed in the intermediate production process, we look at a restricted optimization problem. Also, as the cost shares of these other factors are small, the difference between the solution to the restricted and the unrestricted optimisation problem should be small.

as salmon is marketed through many different channels by many different wholesalers and retailers (see Bjørndal, Salvanes and Andreassen, 1992). It should be noted that most of the imports of frozen salmon are smoked inside the European Union. Hence, demand for imports of frozen salmon must reflect the demand for smoked salmon inside the European Union. It may then seem strange to have a separate demand function for smoked salmon. However, an import duty of 13% on smoked salmon produced outside the European Union ensures that imports of smoked salmon are a specialty, and hence a different product than ordinary smoked salmon.[12]

Domestic production may cause problems when we are using import data, as the data may not reflect the size of the market. Of the countries in the European Union, only Scotland has a significant production of salmon. However, its production is small compared to the European market (less than 10%), and as only the share of the production that is consumed domestically in the UK is not reflected in the data set, our data should reflect the size of the market fairly well. It should also be noted that the almost ideal demand system is also used when estimating international trade models, and it is no problem to interpret the results as import demand (Alston *et al.*, 1990).

A potential problem when estimating the demand system is that supply may be upward sloping. If this is the case, instrumental variables are necessary to obtain consistent parameter estimates. It is likely that the supply curves are upward sloping if there exists a separate European market for salmon as argued by Herrmann and Lin

[12] In some European countries the smoking industry is dominated by a few large firms. However, there is a large trade in smoked salmon between the member countries in the European Union implying that this national dominance may not be used to exploit market power.

(1988), while the supply will be completely elastic in smaller sub-markets such as Europe if there is a world market for salmon (see Bjørndal and Schwindt, 1988; Bjørndal, 1990). To test whether quantities and prices are simultaneously determined, a Hausman test (Hausman, 1978) is utilised, with lagged prices as instruments.[13] The test statistic is 1.138 and is distributed as $\chi^2(6)$. As the critical value for $\chi^2(6)$ at a 5% level is 12.59, we cannot reject the null hypothesis. We will accordingly assume that the prices are predetermined in our demand system. This is also supported by more extensive testing by DeVoretz and Salvanes (1993). One might of course argue how well suited lagged prices are to act as supply shifters, but they are used here for two reasons. Farmed salmon, which constitutes the major share of the supply in Europe, has a lag from when the production decision is made until it is ready for market.[14] Hence lagged prices may be important for the production decision. Moreover, as salmon production is an industry with participants from many different countries, it is unlikely that any country specific supply shifters can have a major impact.[15]

As indicated in Chapter 4, the data series used may be nonstationary. However, as this issue is discussed at length in Chapter 6, and as it does not affect the results, this issue will not be commented upon further here.

---

13 The use of the Hausman test in demand systems was introduced in several recent studies on North American meat demand (Wahl and Hayes, 1990; Eales and Unnevehr, 1993).

14 The lag depends on production site and the size of the marketed fish. Growth time may vary from one year to two years.

15 This argument would be weaker if Europe was a separate market, as Norwegian farmers have a market share of more than 50% for all product forms in Europe, but only around 20% of world supply. The exchange rates between USD and Ecu and NOK and Ecu were also tried as instruments, as these two countries are the largest suppliers of salmon. However, they did not have any effect.

The static system given by (4) was estimated with the homogeneity and symmetry restrictions imposed. While a Durbin-Watson test could not reject the hypothesis of no autocorrelation, as the test statistics in both equations were in the inconclusive zone, the hypothesis could be rejected both using Ljung-Box tests and a LM test (see Table 5.1).[16] Also the homogeneity and symmetry restrictions implied by economic theory were tested using a Wald test, and with the exception of symmetry, these restrictions could be rejected (Table 5.2). These results indicate that a dynamic specification is necessary. Before we give the demand system in (4) a dynamic specification, a more general discussion of dynamic specification of demand systems ensues.

Table 5.1. Tests for autocorrelation

Test	Equation for fresh	Equation for frozen	System
Static Model:			
Durbin Watson	1.32	1.35	
Ljung Box, χ_1^2	5.72*	5.22*	
Ljung Box, χ_4^2	12.12*	16.39*	
LM, χ_4^2			13.47*
LM, χ_{16}^2			43.37*
Dynamic model:			
Ljung Box, χ_1^2	0.02	0.15	
Ljung Box, χ_4^2	4.98	10.52*	
LM, χ_4^2			2.72
LM, χ_{16}^2			14.86

* indicates significant at a 5% significance level

[16] All estimation and tests in this chapter were done with the software package Shazam (White, 1978).

Table 5.2. Homogeneity and symmetry tests

Test	Test Statistic	Degrees of freedom
Static Model:		
Homogeneity	22.85*	2
Symmetry	1.56	1
Homogeneity and symmetry	23.26*	3
Dynamic Model:		
Homogeneity	5.36	2
Symmetry	0.39	1
Homogeneity and synnetry	5.44	3

* indicates significant at a 5% significance level

5.4 The Dynamic Model

An autoregressive distributed lag model is a natural starting point for a dynamic model specification because of its general dynamic structure. Several transformations of the model are possible, and especially the error correction approach advocated by Davidson *et al.* (1978) has been popular during the last decade. The work of Anderson and Blundell (1982; 1983; 1984) introduced this approach to specifications using singular equation systems, allowing a dynamic error correction representation of flexible functional forms such as the almost ideal demand system of Deaton and Muellbauer (1980a). A potential difficulty with this approach is that the system to be estimated is nonlinear. In particular, problems can arise because the parameter estimates may be sensitive to the starting values for the parameters, as the criterion function may have several local optima. Moreover, because the criterion function may have several local optima one is never sure, even when different starting values are used, of obtaining the global optimum. However, this nonlinear specification may be avoided using the Bewley transformation advocated by Wickens and Breusch (1988). We will show one way this transformation can be obtained from an autoregressive distributed lag model, and also that this specification is equivalent to the error correction representation of Anderson and Blundell.

Let *s(t)* denote an $n\times 1$ vector of the budget shares for the *n* goods in the system, *x(t)* an $k\times 1$ vector of the exogenous variables in the system and $\varepsilon(t)$ an $n\times 1$ vector of stochastic errors. Utilising the lag operator *L*, an autoregressive distributed lag model may than be written as

(7) $$\mathrm{B}^*(L)s(t) = \Gamma^*(L)x(t) + \varepsilon(t),$$

where

$$\mathrm{B}^*(L) = \sum_{i=0}^{p} \mathrm{B}_i^* L^i,\ \ \mathrm{B}_0^* = I \ \text{ and } \Gamma^*(L) = \sum_{i=0}^{q} \Gamma_i^* L^i ,$$

and B_i^* and Γ_i^* are $n\times n$ and $n\times k$ matrices of parameters to be estimated. Given that the inverse exists, the long-run parameters implied by (7) are

(8) $$\Pi(q) = \mathrm{B}^*(1)^{-1}\Gamma^*(1) = \left[\sum_{i=0}^{p} \mathrm{B}_i^*\right]^{-1}\left[\sum_{i=0}^{q} \Gamma_i^*\right].$$

However, (7) may be reparameterised to give an observationally equivalent set of equations of the form

(9) $$s(t) = \mathrm{B}^*(1)^{-1}\Gamma^*(1)x(t) + \mathrm{B}^*(1)^{-1}\mathrm{B}(L)\Delta s(t) - \mathrm{B}^*(1)^{-1}\Gamma(L)\Delta\tilde{x}(t) + \mathrm{B}^*(1)^{-1}\varepsilon(t)$$

where Δ is the difference operator and

$$\mathrm{B}(L)=\sum_{i=0}^{p-1}\left(\sum_{j=(i+1)}^{p}B_j^*\right)L^i \text{ and } \Gamma(L)=\sum_{i=0}^{q-1}\left(\sum_{j=(i+1)}^{q}\tilde{\Gamma}_j^*\right)L^i .$$

The tilde indicates that the column/element for the constant term has been deleted. By using (8) and letting $\mathrm{A}=\mathrm{B}^*(1)^{-1}\mathrm{B}(L)$, $\mathrm{H}=-\mathrm{B}^*(1)^{-1}\Gamma(L)$ and $\eta(t)=\mathrm{B}^*(1)^{-1}\varepsilon(t)$, (9) may be rewritten as

(10) $\quad s(t)=\Pi(\theta)x(t)+\mathrm{A}(L)\Delta s(t)+\mathrm{H}(L)\Delta\tilde{x}(t)+\eta(t)$.

This is the Bewley transformation (Wickens and Breusch, 1988). The advantage with (10) compared to (7) is that the long-run parameters, $\Pi(\theta)$, are estimated directly. However, as *s(t)* is present on both sides of the equations in the system (on the right hand side in the term $\Delta s(t)$), the term $\Delta s(t)$ will be correlated with the error term. Ordinary least squares or seemingly unrelated regression, depending on the existence of cross equation restrictions in the system, will therefore not produce consistent estimates of the parameters in (10). This problem is solved by using 2SLS if there are no cross-equation restrictions in the system given by (10) and by 3SLS if cross-equation restrictions are imposed. The levels of the variables vector *s(t)* lagged one period together with the exogenous and predetermined variables in the system can be used as instruments. The parameter estimates and long-run covariance matrices from (7) and (10) are then asymptotically equivalent (Wickens and Breusch, 1988).

As the vector of dependent variables in the almost ideal demand system adds up to unity, the adding up restrictions associated with (8) and (10) are

$\iota'\mathrm{B}_i = m_i\iota'$, $i = 1,\ldots,p-1$, $\qquad \iota'\Gamma_i = 0$, $i = 0,\ldots,q-1$,

$\iota'\mathrm{B}^*(1) = k\iota'$, $\qquad \iota'\Pi = (1\ 0\ 0\ \ldots\ 0)$,

$\iota'\Gamma^*(1) = (k+1\ 0\ 0\ \ldots\ 0),$

where m_i and k are arbitrary constants, $\Sigma m_i=k$, and ι is a vector of ones. The covariance matrix from the equation systems in (7) and (10) is accordingly singular and the systems have a potential redundant variable problem as the vector of lagged dependent variables, which sums to unity, and differenced lagged variables, which sum to zero, appear in each equation. To overcome the singularity and redundant variable problem, Anderson and Blundell (1982) delete one of the variables in the dependent variable vector in addition to the normal deletion of one equation. This also implies that the last column is subtracted from the other columns in each B_i^* matrix.[17] Note that this transformation leaves the parameters of the original B_i^* matrix unidentified (Anderson and Blundell, 1982). Letting a subscript on a matrix denote the deletion of the last row and a superscript denote an *nxn-1* dimensional matrix, the system to be estimated may be written as

(11) $\quad s_n(t) = \Pi_n(\theta)x(t) + A_n^n(L)\Delta s_n(t) + H_n(L)\Delta\tilde{x}(t) + \eta_n(t)$

All the parameters in (10) may be retrieved from (11) using the adding up conditions. The invariance property to which equation is deleted also applies in this type of system (Anderson and Blundell, 1982). Note also that the long-run structure in (11) is given by

(12) $\quad \Pi_n(\theta) = B_n^{n*}(1)^{-1}\Gamma_n^*(1).$

[17] Each B_i^{n*} matrix will then be given as $B_i^{n*} = \begin{bmatrix} b_{11}^i - b_{1n}^i & \cdots & b_{1n-1}^i - b_{1n}^i \\ \vdots & & \vdots \\ b_{n1}^i - b_{nn}^i & \cdots & b_{nn-1}^i - b_{nn}^i \end{bmatrix}$

By premultiplying both sides of (11) with $B_n^{n*}(1)$ and moving the long-run structure to the last lag, (11) may be written as

$$(13)\quad \begin{aligned}\Delta s_n(t) = &-B_n^n(L)\Delta s_n(t) + \Gamma_n(L)\Delta\tilde{x}(t) - \\ &B_n^{n*}(1)s_n(t-p) + \Gamma_n^*(1)x(t-q) + \varepsilon_n(t)\end{aligned},$$

where

$$B_n^n(L) = \sum_{i=1}^{p-1}\left(\sum_{j=0}^{i} B_{nj}^{n*}\right)L^i \text{ and } \Gamma(L) = \sum_{i=0}^{q-1}\left(\sum_{j=0}^{i}\tilde{\Gamma}_{nj}^*\right)L^i.$$

The error correction specification of Anderson and Blundell (1982) is easily obtained from (13) using (12). The equation system may then be written as

$$(14)\quad \begin{aligned}\Delta s_n(t) = &-B_n^n(L)\Delta s_n(t) + \Gamma_n(L)\Delta\tilde{x}(t) - \\ &B_n^{n*}(1)(s_n(t-p) - \Pi_n(\theta)x(t-q)) + \varepsilon_n(t)\end{aligned}$$

The long-run relationship is found inside the parenthesis, which also makes the system nonlinear.

The specification based on the Bewley transformation given by (11) and Anderson and Blundell's specification (14) is observationally equivalent (in small samples one might expect some differences as the long-run relationships in (11) and (14) appear at different lags).[18] However, the specification given by (11) may be easier to use in applied work, because of its linear specification.

[18] A version of the Bewley transformation is used by Kesavan *et al.* (1993) in an AIDS model. However, their specification is very restrictive as only within equation dynamics are allowed, restricting the cross equation correlation to be contemporary and implying that the parameters are equal for the lagged dependent variables in all equations (Berndt and Savin, 1975).

5.5 Dynamic Specification and Empirical Results

As noted in Section 5.3, the static specification (4) failed the autocorrelation and homogeneity and symmetry tests, indicating misspecified dynamics. Hence, to account for the missing dynamics, the equations in (4) are transformed into a dynamic system as given by (11). Four lags were necessary to incorporate the dynamics in this specification when the homogeneity and symmetry restrictions are imposed on the system. However, a search for a more parsimonious dynamic model indicated that the last lag for the prices and expenditure could be deleted from both equations. With this specification, the hypothesis of no autocorrelation cannot be rejected using the LM test, while the Ljung Box test rejects the hypothesis of no autocorrelation in the equation for frozen salmon (Table 5.1). Here, the advantage with the LM test being a test for autocorrelation in the system is evident, as the Ljung-Box test could reject the hypothesis of no autocorrelation in one equation, but not in the other. The specification in equation (15) therefore seems to include the necessary dynamics.

With the equation for smoked salmon deleted, the estimated system is given as

$$\begin{bmatrix} w_{Ft} \\ w_{Zt} \end{bmatrix} = \begin{bmatrix} \alpha_F \\ \alpha_Z \end{bmatrix} + \begin{bmatrix} \alpha_{TF} \\ \alpha_{TZ} \end{bmatrix} t + \begin{bmatrix} \gamma_{FF} & \gamma_{FZ} & \gamma_{FS} \\ \gamma_{ZF} & \gamma_{ZZ} & \gamma_{ZS} \end{bmatrix} \begin{bmatrix} \ln p_{Ft} \\ \ln p_{Zt} \\ \ln p_{St} \end{bmatrix} + \begin{bmatrix} \beta_F \\ \beta_Z \end{bmatrix} \ln\left(\frac{X_t}{P_t}\right) +$$

(15)

$$\sum_{i=0}^{3} \begin{bmatrix} \theta_{FF,i} & \theta_{FZ,i} \\ \theta_{ZF,i} & \theta_{ZZ,i} \end{bmatrix} \begin{bmatrix} \Delta w_{Ft-i} \\ \Delta w_{Z-it} \end{bmatrix} + \sum_{i=0}^{2} \begin{bmatrix} \varphi_{FF,i} & \varphi_{FZ,i} & \varphi_{FS,i} \\ \varphi_{ZF,i} & \varphi_{ZZ,i} & \varphi_{ZS,i} \end{bmatrix} \begin{bmatrix} \Delta \ln p_{Ft-i} \\ \Delta \ln p_{Zt-i} \\ \Delta \ln p_{St-i} \end{bmatrix} +$$

$$\sum_{i=0}^{2} \begin{bmatrix} \lambda_{F,i} \\ \lambda_{Z,i} \end{bmatrix} \Delta \ln\left(\frac{X_{t-i}}{P_t - i}\right) + \begin{bmatrix} \eta_{Ft} \\ \eta_{Zt} \end{bmatrix}$$

The terms Δw_{it} introduce a simultaneity problem in the equations. As noted in the preceding section, this is solved as suggested by Wickens and Breusch (1988) with an instrumental variable approach. A vector of the levels of the shares in the system lagged one period is used as instruments together with the predetermined variables in the system. The system must then be estimated with an iterative 3SLS procedure when the homogeneity and symmetry restrictions are imposed to keep the system invariant to which equation is deleted (Berndt and Wood, 1975).

One of the main results from Anderson and Blundell's studies (1982; 1983; 1984) is that with a proper dynamic specification of the estimated equations, the homogeneity and symmetry restrictions implied by economic theory are accepted. These restrictions are tested here using a Wald test. The null hypothesis of homogeneity and symmetry cannot be rejected either separately or jointly, as may be seen in Table 5.2. These restrictions are accordingly imposed in the remaining analysis. It should be noted that the hypothesis of homogeneity and symmetry was rejected in all specifications with more limited dynamics. Hence, the importance of a dynamic specification is seen not only in providing valid inference by avoiding autocorrelation, but also in providing a specification in accordance with economic theory.

The parameter estimates with this specification are presented in Table 5.3, while the uncompensated and compensated elasticities at means are presented in Tables 5.4 and 5.5, respectively. The results are in line with what is reported in the literature (DeVoretz, 1982; Kabir and Ridler, 1984; Bird, 1986; Herrmann and Lin, 1988; Bjørndal, 1990; Bjørndal, Salvanes and Andreassen, 1992; DeVoretz and Salvanes, 1993; Herrmann, Mittelhammer and Lin, 1993; Wessells and Wilen, 1993; 1994; Bjørndal, Gordon and Salvanes, 1994 and Chapter 4). Both the uncompensated and compensated own-price elasticity for fresh salmon are own-price elastic, and the magnitude of the uncompensated elasticity is also significantly larger than unity. The own-price elasticities for frozen and smoked salmon are own-price inelastic, but the magnitude of the uncompensated own-price elasticity for smoked salmon is very close to, and not significantly different from unity. All the own-price elasticities are significantly different from zero. The demand for salmon is regarded as own-price elastic in the literature, although it is mostly fresh or an aggregate category of salmon that has been studied. It is accordingly a little bit surprising that the demand for frozen and smoked salmon is found to be own-price inelastic, although this is also reported in Chapter 4. However, frozen salmon is mostly used as an input in the smoking industry (although fresh salmon can be used) and large quantities of frozen Pacific salmon are also available the whole year. Hence, frozen salmon is probably the product category with the keenest competition, and the low own-price effect therefore seems reasonable. Even though smoked salmon mostly is imported as a specialty, it is likely to compete with smoked salmon produced in the European Union. The weak own-price effect is therefore also reasonable here. This difference in own-price effects also highlights the importance of considering the different product forms of salmon, and not analysing only one or an aggregate category.

The rather low magnitudes of the own-price elasticities, and particularly for fresh salmon, also seem to confirm a trend in the literature in reporting own-price elasticities with lower magnitudes when more recent data sets are used. An advantage with the almost ideal demand system compared to a single equation specification linear in the logarithms of the variables, is that the elasticities are allowed to vary over time. This is here exploited to plot the own-price elasticities using the annual average budget shares in Figure 5.1. As one can see, the magnitude of the own-price elasticity for fresh salmon decreases substantially over the period 1981-1992, while the elasticities for frozen and smoked salmon are fairly stable. Hence, the increased supply of fresh salmon has made demand less elastic.

Fresh and frozen salmon are found to be substitutes as expected, and they are significantly different from zero, except for the compensated elasticity in the equation for fresh salmon. Fresh and smoked salmon are also found to be substitutes, but only the compensated elasticities are significantly different form zero. Frozen and smoked salmon are found to be complements, but only the uncompensated elasticity between smoked and frozen salmon in the equation for smoked salmon is significantly different from zero. The complementary relationship between frozen and smoked salmon may be a little bit surprising. However, as there is a large smoking industry in several European countries (in particular France and Germany) which mostly uses frozen salmon as an input factor, with smoked salmon imported only as a specialty, the result does not seem unreasonable.

Table 5.3. Parameter estimates with standard errors.

Equation	Fresh		Frozen	
Variable	Estimate	St. Dev.	Estimate	St. Dev.
$\Delta freshs_t$	1.487	(0.933)	-2.194**	(1.248)
$\Delta frozs_t$	1.398*	(0.696)	-1.898**	(0.943)
$\Delta freshp_t$	-0.069	(0.101)	0.187	(0.132)
$\Delta frozp_t$	-0.194**	(0.098)	0.163	(0.138)
$\Delta smokep_t$	0.763*	(0.245)	-1.013*	(0.339)
Δinc_t	0.073	(0.701)	-0.096	(0.104)
$\Delta freshs_{t-1}$	2.088*	(0.122)	-2.605*	(0.970)
$\Delta frozs_{t-1}$	1.862*	(0.591)	-2.238*	(0.818)
$\Delta freshp_{t-1}$	-0.194	(0.122)	0.408*	(0.163)
$\Delta frozp_{t-1}$	-0.209*	(0.099)	0.161	(0.139)
$\Delta smokep_{t-1}$	1.005*	(0.303)	-1.311*	(0.424)
Δinc_{t-1}	0.110**	(0.067)	-0.155**	(0.093)
$\Delta freshs_{t-2}$	2.160*	(0.779)	-3.088*	(1.078)
$\Delta frozs_{t-2}$	1.964*	(0.623)	-2.688*	(0.862)
$\Delta freshp_{t-2}$	-0.294*	(0.117)	0.491*	(0.159)
$\Delta frozp_{t-2}$	-0.339*	(0.121)	0.418*	(0.170)
$\Delta smokep_{t-2}$	1.059*	(0.304)	-1.421*	(0.425)
Δinc_{t-2}	0.153*	(0.686)	-0.232*	(0.095)
$\Delta freshs_{t-3}$	1.002**	(0.675)	-1.678**	(0.839)
$\Delta frozs_{t-3}$	0.487	(0.348)	-0.732	(0.485)
$freshp_t$	-0.179*	(0.072)	0.103	(0.084)
$frozp_t$	0.104	(0.085)	0.007	(0.121)
$smokep_t$	0.075	(0.049)	-0.113*	(0.055)
inc_t	0.087	(0.103)	-0.226**	(0.134)
Trend	0.004*	(0.002)	-0.001	(0.003)
Constant	-0.849	(1.202)	3.231*	(1.569)
R^2	0.956		0.918	

*indicates significant at a 5% significance level and ** indicates significant at a 10% significance level.

Table 5.4. Uncompensated elasticities[a,b]

	Fresh	Frozen	Smoked	Expenditure
Fresh	-1.584*	0.186	0.155	1.242*
	(0.165)	(0.305)	(0.159)	(0.287)
Frozen	0.441*	-0.756*	-0.146	0.462
	(0.179)	(0.364)	(0.139)	(0.320)
Smoked	0.115	-0.770*	-0.975*	1.629*
	(0.174)	(0.296)	(0.311)	(0.316)

*indicates significant at a 5% significance level and ** indicates significant at a 10% significance level.

[a] Standard deviations are in parentheses.

[b] The uncompensated elasticities are given as

$$\eta_{ij} = \frac{\gamma_{ij}}{w_i} - \beta_i \frac{w_j}{w_i} - \delta, \ \delta = 1, \ i = j, \ \delta = 0, \ i \neq j.$$

Table 5.5. Compensated elasticities[a,b]

	Fresh	Frozen	Smoked	Expenditure
Fresh	-1.137*	0.708*	0.429*	1.242*
	(0.200)	(0.236)	(0.138)	(0.287)
Frozen	0.607*	-0.562**	-0.048	0.462
	(0.202)	(0.288)	(0.132)	(0.320)
Smoked	0.702*	-0.085	-0.607*	1.629*
	(0.226)	(0.252)	(0.202)	(0.316)

*indicates significant at a 5% significance level and ** indicates significant at a 10% significance level.

[a] Standard deviations are in parentheses.

[b] The compensated elasticities are given as $\eta^*_{ij} = \frac{\gamma_{ij}}{w_i} + w_j - \delta, \ \delta = 1, \ i = j, \ \delta = 0, \ i \neq j.$

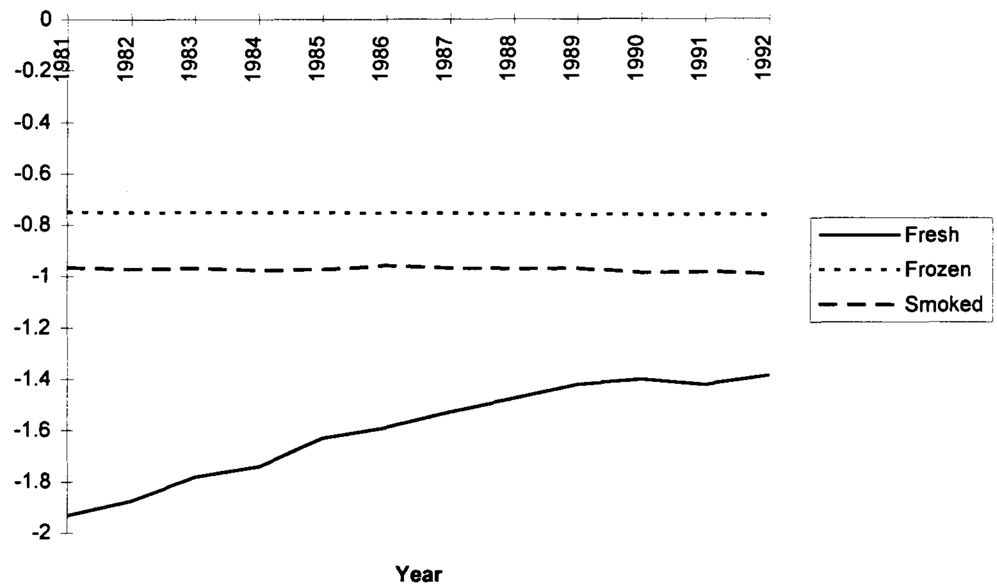


Figure 5.1. Own-price elasticities

Both fresh and smoked salmon are found to be expenditure elastic. However, as only the elasticity for smoked salmon is significantly larger than unity, only smoked salmon seem to be a luxury product. Frozen salmon is found to be necessity, and the elasticity is not significantly different from zero. The rather low magnitude on the elasticity for fresh salmon is somewhat surprising, as most of the studies cited above find fresh salmon to be a luxury good. This might be explained by the system approach together with the recent data set, which has not been utilised in most of the literature. In the studies where a system is used (Wessells and Wilen, 1993; 1994 and Chapter 4) fresh salmon is found to be expenditure elastic, but barely so. With the exception of Chapter 4, the demand for frozen and smoked salmon is not considered in the above mentioned studies. However, the results seem reasonable, with smoked salmon as the only luxury good, and with fresh and smoked salmon as most own-price elastic. Note however, that the magnitudes of the elasticities differ from those reported in Chapter 4 to some extent, even though the main conclusions seem to be similar.

Table 5.6. Uncompensated elasticities from static model[a,b]

	Fresh	Frozen	Smoked	Expenditure
Fresh	-1.284	-0.080	0.060	1.304
	(0.123)	(0.167)	(0.096)	(0.079)
Frozen	0.222	-0.611	-0.107	0.496
	(0.135)	(0.215)	(0.119)	(0.093)
Smoked	0.041	-0.612	-0.893	1.463
	(0.139)	(0.215)	(0.223)	(0.102)

[a] Standard deviations are in parentheses.
[b] The uncompensated elasticities are given as

$$\eta_{ij} = \frac{\gamma_{ij}}{w_i} - \beta_i \frac{w_j}{w_i} - \delta, \quad \delta = 1, \ i = j, \ \delta = 0, \ i \neq j.$$

To facilitate a comparison with a static specification, uncompensated elasticities from the static specification given in (1) with homogeneity and symmetry imposed were also computed. These elasticities are shown in Table 5.6. This may be of interest, as this has been the normal approach to specifying systems of consumer demand functions. However, keep in mind that the homogeneity and symmetry restrictions are rejected by the data in this model formulation and that the presence of autocorrelation invalidates normal inference. Most elasticities differ somewhat in magnitude, but there are no major qualitative differences. Hence, the omission of the dynamics do not seem to give too misleading results in this case.

A weakness with the specification based on the Bewley transformation compared to Anderson and Blundell's specification, is that it is not possible to test the hypothesis that the model is an autoregressive errors model (Berndt and Savin, 1975). Our specification nests this hypothesis only nonlinearly, and if it is of importance to test this hypothesis, Anderson and Blundell's nonlinear specification is more suitable. As the estimates of the long-run parameters in a model with autoregressive errors do not differ from the parameters in the static model, this might give an indication of whether a model with autoregressive errors is reasonable. However, in our case it is hard to say, as the results are similar, but there are also differences in the magnitudes between the two approaches. Without undertaking a test for the hypothesis of autoregressive errors, it is accordingly difficult to judge whether it would be accepted in our case.

5.6 Concluding Remarks

To estimate the demand for fresh, frozen and smoked salmon in the European Union, a demand system based on the almost ideal demand system of Deaton and Muellbauer (1980a) was specified. To incorporate dynamics in the specification, a Bewley transformation of an error correction model was utilised. This specification leaves the dynamic specification of the demand relationships linear, in contrast to earlier approaches (Anderson and Blundell, 1983, 1984; Veall and Zimmermann, 1986). The singularity and redundant variables problems caused by the adding up conditions are solved as described by Anderson and Blundell (1982).

It was suggested to use the LM test of Godfrey (1981) also in demand systems. The main advantages with the LM test in this context compared to the traditional Durbin-Watson or Ljung-Box tests is the ability to specify cross equation serial correlation as a part of the alternative hypothesis and that it is a test for serial correlation in the system, not equation by equation. Also, in singular equation systems it is an advantage that the LM test is invariant to which equation is deleted. Our results may indicate that the Durbin-Watson test has weak power in our case, as it could not reject the hypothesis of no autocorrelation in the static model. Both Ljung-Box tests and the LM test rejected this hypothesis. In the dynamic model, some of the advantage with the LM test being a test for autocorrelation in the system became evident, as the Ljung-Box test could reject the hypothesis of no autocorrelation in the equation for frozen salmon, but not for fresh salmon.

The empirical results are reasonable. The homogeneity and symmetry restrictions implied by economic theory are not rejected with the dynamic specification. The computed elasticities are mostly in accordance with what is reported in the literature. However, the magnitudes of the own-price and expenditure elasticities for fresh salmon are lower than what is normally reported in the literature. This seems to confirm a trend, where lower magnitudes are reported when more recent data sets are used. For frozen and smoked salmon there exist few comparable results in the literature, but the results indicate the importance of considering more than one product form if one is to gain knowledge about the demand structure for salmon.

REFERENCES

Alston, J. M., C. A. Carter, R. Green, and D. Pick (1990) "Whither Armington Trade Models," *American Journal of Agricultural Economics*, 72, 455-468.

Anderson, G. J. and R. W. Blundell (1982) "Estimation and Hypothesis Testing in Dynamic Singular Equation Systems," *Econometrica,* 50, 1559-1571.

Anderson, G. J. and R. W. Blundell (1983) "Testing Restrictions in a Flexible Demand System: An Application to Consumers' Expenditure in Canada," *Review of Economic Studies,* 50, 397-410.

Anderson, G. J. and R. W. Blundell (1984) "Consumer Non-Durables in the U.K.: A Dynamic Demand System," *Economic Journal,* 94, 35-44.

Barten, A. P. (1969) "Maximum Likelihood Estimation of a Complete System of Demand Equations," *European Economic Review*, 1, 7-73.

Berndt, E. R. and N. E. Savin (1975) "Estimation and Hypothesis Testing in Singular Equation Systems with Autoregressive Disturbances," *Econometrica*, 43, 937-958.

Berndt, E. R. and D. O. Wood (1975) "Technology, Prices, and the Derived Demand for Energy," *Review of Economics and Statistics,* 57, 259-268.

Bird, P. (1986) "Econometric Estimation of World Salmon Demand," *Marine Resource Economics*, 3, 169-182.

Bjørndal, T. (1990) *The Economics of Salmon Aquaculture*, Oxford: Blackwell.

Bjørndal, T., D. V. Gordon, and K. G. Salvanes (1994) "Elasticity Estimates of Farmed Salmon Demand in Spain and Italy," *Empirical Economics*, 4, 419-428.

Bjørndal, T., K. G. Salvanes, and J. H. Andreassen (1992) "The Demand for Salmon in France: the Effects of Marketing and Structural Change," *Applied Economics,* 24, 1027-1034.

Bjørndal, T. and R. Schwindt. (1988) "An International Analysis of the Industrial Economics of Salmon Aquaculture," Institute of Fisheries Economics, Norwegian School of Economics and Business Administration. Working Paper 3/88.

Buse, A. (1994) "Evaluating the Linearized Almost Ideal Demand System," *American Journal of Agricultural Economics*, 76, 781-793.

Davidson, J. E. H., D. F. Hendry, F. Srba, and S. Yeo (1978) "Econometric Modelling of the Aggregate Time-Series Relationship Between Consumers' Expenditure and Income in the United Kingdom," *Economic Journal,* 88, 661-92.

Davidson, R. and J. G. MacKinnon (1993) *Estimation and Inference in Econometrics*, Oxford: Oxford University Press.

Deaton, A. S. and J. Muellbauer (1980a) "An Almost Ideal Demand System," *American Economic Review,* 70, 312-326.

Deaton, A. S. and J. Muellbauer (1980b) *Economics and Consumer Behavior*, New York: Cambridge University Press.

DeVoretz, D. (1982) "An Econometric Demand Model for Canadian Salmon," *Canadian Journal of Agricultural Economics*, 30, 49-60.

DeVoretz, D. J. and K. G. Salvanes (1993) "Market Structure for Farmed Salmon," *American Journal of Agricultural Economics,* 30, 49-60.

Eales, J. S. and L. J. Unnevehr (1993) "Simultaneity and Structural Change in U.S. Meat Demand," *American Journal of Agricultural Economics*, 75, 259-268.

Gardner, B. L. (1975) "The Farm-Retail Price Spread in a Competitive Food Industry," *American Journal of Agricultural Economics*, 57, 399-409.

Goodwin, B. K. (1994) "Oligopsony Power: A Forgotten Dimension of Food Marketing," *American Journal of Agricultural Economics*, 76, 1163-1165.

Godfrey, L. G. (1981) "On the Invariance of the Lagrange Multiplier Test with Respect to to Certain Changes in the Alternative Hypothesis," *Econometrica*, 49, 1443-1455.

Gordon, D. V., K. G. Salvanes and F. Atkins (1993) "A Fish Is a Fish Is a Fish: Testing for Market Linkage on the Paris Fish Market," *Marine Resource Economics*, 8, 331-343.

Guilkey, D. K. and P. Schmidt (1973) "Estimation of Seemingly Unrelated Regressions with Vector Autoregressive Errors," *Journal of the American Statistical Association*, 68, 642-647.

Hausman, J. A. (1978) "Specification Tests in Econometrics," *Econometrica*, 46, 1251-1271.

Herrmann, M. R. and B. H. Lin (1988) "The Demand and Supply of Norwegian Atlantic Salmon in the United States and the European Community," *Canadian Journal of Agricultural Economics,* 453-464.

Herrmann, M. L., R. C. Mittelhammer, and B. H. Lin (1993) "Import Demand for Norwegian Farmed Atlantic Salmon and Wild Pacific Salmon in North America, Japan and the EC," *Canadian Journal of Agricultural Economics*, 41, 111-125.

Jorgenson, D. W. (1964) "Minimum Variance, Linear, Unbiased Seasonal Adjustment in Economic Time Series," *Journal of the American Statistical Association*, 59, 681-725.

Kabir, M. and N. B. Ridler (1984) "The Demand for Atlantic Salmon in Canada," *Canadian Journal of Agricultural Economics*, 32, 560-568.

Kesavan, T., Z. A. Hassan, H. H. Jensen, and S. R. Johnson (1993) "Dynamics and Long-Run Structure in U.S. Meat Demand," *Canadian Journal of Agricultural Economics*, 41, 139-153.

Moschini, G. (1995) "Units of Measurement and the Stone Price Index in Demand System Estimation," *American Journal of Agricultural Economics*, 77, 63-68.

Pashardes, P. (1993) "Bias in Estimating the Almost Ideal Demand System with the Stone Index Approximation," *Economic Journal*, 103, 908-915.

Pollak, R. A. (1970) "Habit Formation and Dynamic Demand Functions," *Journal of Political Economy*, 78, 745-763.

Veall, M. R. and K. F. Zimmermann (1986) "A Monthly, Dynamic Consumer Expenditure System for Germany with Different Types of Households," *Review of Economics and Statistics*, 68, 256-264.

Wahl, T. I. and D. J. Hayes (1990) "Demand System Estimation with Upward-Sloping Supply," *Canadian Journal of Agricultural Economics*, 38, 107-122.

Wessells, C. R. and J. E. Wilen (1993) "Ecomomic Analysis of Japanese Household Demand for Salmon," *Journal of the World Aquaculture Society*, 24, 361-378.

Wessells, C. R. and J. E. Wilen (1994) "Seasonal Patterns and Regional Preferences in Japanese Household Demand for Seafood," *Canadian Journal of Agricultural Economics*, 42, 87-103.

White, K. J. (1978) "A General Computer Program for Econometric Methods-SHAZAM," *Econometrica,* 46, 239-240.

Wickens, M. R. and T. S. Breusch (1988) "Dynamic Specification, the Long-Run and the Estimation of Transformed Regression Models," *Economic Journal,* 98, 189-205.

Wohlgenant, M. K. (1989) "Demand for Farm Output in a Complete System of Demand Functions," *American Journal of Agricultural Economics*, 71, 241-252.

6: INFERENCE IN DEMAND EQUATIONS WITH NONSTATIONARY DATASERIES

6.1 Introduction

It is widely recognised that most economic data series tend to be nonstationary. Nonstationary data series may cause problems in econometric analysis as they, in general, invalidate normal inference theory. However, in some special cases, normal inference theory will also apply when using nonstationary data series (Phillips, 1991). This will be the case when the data series are cointegrated and the regressors in the long-run relationships are strongly exogenous. We will exploit this to argue that, in most estimated demand equations based on microeconomic theory, normal inference theory will apply also when the data series are nonstationary.

In applied work, the issue of nonstationarity has mostly been addressed in applied macroeconomics. In demand system analysis it is only very recently this issue has received some attention (Chambers, 1993; Ng, 1995 and Chapter 4). It is somewhat surprising that one of the most active research areas of applied econometrics during the 1970s and early 1980s, the flexible functional form specifications, has remained almost untouched by the recent advances in time series analysis, and completely ignored the potential problems which may be caused by nonstationary data series. This is the case, even though dynamic specifications of flexible functional forms were discussed from the mid 1970s (see e.g. Berndt and Savin, 1975), and the error correction framework of Davidson *et al.* (1978), which has been so important in the time series literature, was quickly adapted to flexible functional form specifications by Anderson and Blundell (1982; 1983).

The issue has been noticed in single equation demand equation specifications, which fit more straightforwardly into the error correction framework of Davidson *et al.* (1978). Error correction models have been used to estimate demand equations after the data series have been found to be nonstationary but cointegrated, see e.g. Johnson *et al.* (1992). However, the issue of inference on the long-run parameters has not received much attention in these cases.[1]

Phillips (1991) has recently shown that, when nonstationary data series are cointegrated, and the regressors in the equations containing the long-run relationships are strongly exogenous, normal inference theory will apply. While strong exogeneity and cointegration are restrictive assumptions in most macroeconomic models, they are often more reasonable in microeconomic models with aggregated time series data under some assumptions about the market structure.

In this chapter, we will argue that when estimating demand equations, the assumptions of cointegration and strong exogeneity are often reasonable, and that normal inference theory may apply also when the data series are nonstationary. In fact, assumptions comparable to cointegration and strong exogeneity are regularly made when estimating demand functions, although they are stated somewhat differently. That the nonstationary data series are cointegrated implies that there exists a long-run relationship between the data series. This is a trivial assumption, as there would be little sense in estimating a demand equation if there was not a long-run relationship between price and quantity. Assuming that the agents are price takers, as will be the case for example if the good demanded is supplied competitively, makes the price strongly exogenous. If these assumptions hold, normal inference theory will apply when estimating demand equations also when the data series are nonstationary.

[1] However, the issue is thoroughly discussed in several macroeconomic demand relationships, including money demand.

This chapter is organised as follows. In Section 6.2, we will discuss cointegration. In Section 6.3, we will show Phillips' (1991) asymptotic results and further discuss them in relation to demand equations. In Section 6.4, some further remarks as to when prices may be regarded as exogenous in demand systems are offered, before concluding remarks are given in Section 6.5.

6.2 Cointegration

Cointegration is a key concept when dealing with nonstationary data series because the existence of a cointegration vector is a necessary condition for nonstationary variables to form a long-run relationship (Engle and Granger, 1987). Cointegration must therefore be verified in regressions with nonstationary data, to avoid spurious regression problems. A regression on nonstationary data series without a cointegration relationship will produce a spurious relationship (Granger and Newbold, 1986; Phillips, 1986). In this section the concept of cointegration and testing for cointegration is discussed as this is one of the key concepts if ordinary inference theory is to be valid with nonstationary data series.

One may of course wonder how the variables in a demand equation may not form a cointegration relationship. However, one would expect no relationship between price and quantity when the adjustment cost is too large, e.g. when a factor is fixed (or quasi-fixed so that we can not detect the relationship with a limited data set) (see e.g. Brown and Christensen, 1981), or when supply is rationed. Hence, tests for cointegration in demand equations with nonstationary data may be an advantage, as it is also a test on the specification of the system.

A data series which has to be differenced *d* times to become stationary is said to be integrated of order *d*, denoted $x_t \sim I(d)$. In general, a linear combination of variables integrated of the same order will produce residuals integrated of the same order. In the classical Ordinary Least Squares (OLS) assumptions it is assumed that all variables are stationary, as this is the only way to guarantee stationary residuals. Regressions on nonstationary variables will in general provide spurious relationships as normal inference theory does not apply (Granger and Newbold, 1986; Phillips, 1986). However, in the special case when two or more nonstationary data series integrated of the same order form a long-run relationship, i.e., they move together over time, a regression on these variables will produce stationary residuals. In this case the variables are said to be cointegrated. Cointegration is given the following definition by Engle and Granger (1987):

> *The components of the vector x_t are said to be cointegrated of order d,b, denoted $x_t \sim CI(d,b)$ if (i) all components of x_t are I(d); (ii) there exists a vector α ($\neq 0$) so that $z_t = \alpha' x_t \sim I(d-b)$, $b>0$. The vector α is called the co-integrating vector.*

Hence, when the data series in x_t is integrated of the same order d, there are two cases where we may obtain stationary residuals from a regression on the vector x_t; (a) the data series in x_t are themselves stationary or; (b) the data series are cointegrated of order d, or $x_t \sim CI(d,d)$. For the purpose of this paper, we are only interested in the case when the residuals from the cointegration relation are stationary, as we are only interested in stable long-run relationships. Note that a regression on stationary variables always gives a long-run relationship if the estimated parameters are significantly different from zero.

Engle and Granger propose to use a Dickey-Fuller test (Dickey and Fuller, 1979; 1981) to test the residuals in a static regression of what is thought of as the long-run relationship for stationarity, as a test for cointegration, given that the data series are integrated of the same order.[2] However, it is easily seen using the definition of

[2] Note that the test has a nonstandard distribution. Critical values can be found in MacKinnon (1991).

cointegration given above that the residuals in static regressions are stationary only if all the data series are either a) stationary in their levels or b) the nonstationary data series are cointegrated. It is therefore sufficient to test the residuals from a static regression of the possible long-run relationship for stationarity to validate the existence of a long-run relationship; it is not necessary to test each of the data series for its order of integration.

6.3 Inference in Demand Equations with Cointegrated Data Series

In this section, the results from Phillips (1991) which are used to validate ordinary inference in demand equation specifications with nonstationary data series, will be presented more formally. For the flexible functional forms, we will in the following restrict ourselves to systems of demand equations, as these specifications apply to both the consumer and producer sides. On the consumer side, the analysis has traditionally dealt only with systems of demand equations (see e.g. Deaton and Muellbauer, 1980b or Pollak and Wales, 1992). Systems of demand equations have also been the most common specification on the production side in dynamic specifications (see e.g. Berndt and Savin, 1975; Anderson and Blundell, 1982; or Friesen, 1992), but cost or profit functions have often also been estimated in static specifications (see e.g. Christensen *et al.*, 1973 or Berndt and Wood, 1975). Duality theory ensures that no information regarding consumer preferences or production technology is lost by estimating only a system of demand equations.

Let y_t be an n-vector $I(1)$ process and u_t be an n-vector stationary time series whose long-run covariance matrix is nonsingular. We partition these vectors into subvectors of dimension n_1 and n_2 with $n=n_1+n_2$ and assume that the data generating mechanism for y_t is the cointegrated system;

(1) $y_{1t} = By_{2t} + u_{1t}$,

(2) $\Delta y_{2t} = u_{2t}$.

Here B is an $n_1 \times n_2$ matrix of coefficients giving the long-run equilibrium relationships in the system, and u_{1t} might be thought of as representing stationary deviations from equilibrium.[3] Equations (1) and (2) may also be written as a set of simultaneous equations,

(3) $$\begin{bmatrix} I & -B \\ 0 & I \end{bmatrix} y_t = \begin{bmatrix} 0 \\ I \end{bmatrix} y_{2t-1} + u_t .$$

Equation (3) is one version of Phillips' well-known triangular error correction system (Phillips, 1991). Let the innovations in (3), u_t, satisfy the invariance principle

(4) $$T^{-1/2} \sum_{1}^{[Tr]} u_t \Rightarrow S(r) \equiv BM(\Omega),$$

where $BM(\Omega)$ is a vector Brownian motion with covariance matrix Ω. This will be true if u_t is $iid(0,\Omega)$ or a strictly stationary and ergodic sequence of martingale differences with conditional covariance matrix Ω. We partition conformably with y the covariance matrix Ω and define $\Omega_{11\cdot2} = \Omega_{11} - \Omega_{12}\Omega_{22}^{-1}\Omega_{21}$. Similarly, we partition the limit process S as $S' = (S_1', S_2')$ and define the component process $S_{1\cdot2} = S_1 - \Omega_{12}\Omega_{22}^{-1}S_2 \equiv BM(\Omega_{11\cdot2})$ which is independent of S_2.

Phillips (1991) shows that Maximum Likelihood Estimation of (3) with the unit roots imposed gives estimators with a standard distribution. He also shows that the Full Information Maximum Likelihood (FIML) estimator and the OLS estimator (see also Phillips and Loretan (1991)) of the parameters B in the system given by (3) generally is distributed as;

(5) $$T(\hat{B} - B) \Rightarrow \left(A \int_0^1 dSS_2'\right)\left(\int_0^1 S_2 S_2'\right)^{-1} \equiv \left(\int_0^1 dS_{1\cdot2}S_2'\right)\left(\int_0^1 S_2 S_2'\right)^{-1} + \Omega_{12}\Omega_{22}^{-1}\left(\int_0^1 dS_2S_2'\right)\left(\int_0^1 S_2 S_2'\right)^{-1}$$

In general, the limit distribution in (5) is a linear combination of the "unit root" distribution given by the term $\left(\int_0^1 dS_2S_2'\right)\left(\int_0^1 S_2 S_2'\right)^{-1}$ and the compound normal

[3] Deterministic components are easily incorporated in the system given in equations (1) and (2) as shown by Hansen (1992).

distribution given by the term$\left(\int_0^1 dS_{1.2}S'\right)\left(\int_0^1 S_2\,S_2'\right)^{-1}$. However, if Ω_{12}=0, i.e., y_{2t} is strongly exogenous for the parameters B, the presence of the "unit root" distribution in (5) disappears, and (5) reduces to a normal distribution. In this case, OLS estimation on (1) is equivalent to Maximum Likelihood Estimation of (1) and (2) if B are unrestricted. If there are cross equation restrictions in B, Seemingly Unrelated Regression (SUR) are necessary to obtain Maximum Likelihood Estimates of the system given by (1).

Letting y_{1t} be interpreted as factor or expenditure shares and y_{2t} as prices and output or expenditure, (1) may be interpreted as the demand system from several flexible functional forms, e.g. the share equations in either the translog of Christensen *et al.* (1973) or the Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980a).[4] Letting y_{1t} be only a single quantity, (1) can also be interpreted as a single demand equation. The asymptotics developed by Phillips (1991) therefore also validate normal inference theory for these approaches when the data series are nonstationary, provided that the data series are cointegrated and the regressors are strongly exogenous. With time series data, autocorrelation may still make the regressors from static regressions like (1) poor candidates for inference. However, this may be handled both parametrically with error correction models and semiparametrically (Phillips and Loretan, 1991).

Note also that the triangular error correction system assumes the number of cointegration vectors (long-run relationships) as known. When estimating a demand system, the specification gives the number of long-run relationships. Accordingly, it is

[4] One may wonder how the shares, which are bounded between zero and one, can be nonstationary. Several factors indicate that this must be so. If prices are nonstationary, as often seem to be the case, the shares must be nonstationary if there is a long-run relationship between prices and shares. This follows from the notion of cointegration. Also, even if the shares are bounded, there is no guarantee that the series are mean-reverting, as implied by stationarity.

not necessary to use a test for cointegration that decides the number of cointegration vectors in the system, e.g. the Johansen test (Johansen, 1988).

6.4 Exogeneity in Demand Equations

The idea of exogeneity is that a variable is exogenous if it is determined outside the system under analysis. Engle, Hendry and Richard (1983) show that if a variable is predetermined and is not Granger caused by the endogenous variables in the system, the variable is strongly exogenous. We will not give a more precise definition of exogeneity here, but refer to Engle *et al.* (1983). What is important here, is that microeconomic theory for some market structures implies that the prices in a demand equation are strongly exogenous, and accordingly, normal inference theory will apply. The will be the case for all market structures where the supply may be regarded as completely elastic for the agents in question. The prices will, for instance, be exogenous when the product in question is supplied competitively. In this case, the prices are determined by the production technology which exhibits constant returns to scale at the industry level, and cannot be Granger caused by the demanded quantities. The prices will also be exogenous when the demand studied is very small compared to the total supply, such that shifts in demand will not affect price. This may hold for example for the demand from a small economy for a commodity supplied on the world market. Note that no argument of atomistic behavior of each single consumer or other micro level assumptions are used to argue that prices must be exogenous. This is because the data considered here are time series and accordingly aggregated, and the validity of micro level arguments for exogeneity is doubtful in this context (Thurman, 1986). A more thorough discussion of when the prices can be regarded as exogenous in demand equations can also be found in Thurman (1986) and in Chapter 2.[5]

Expenditure in consumer demand equations and output in factor demand equations are also normally assumed to be exogenous in applied work, and there seems to be little discussion about this, as there is for prices which might be determined simultaneously with quantities.[6] This assumption is of course also necessary to validate normal inference theory when the data series are nonstationary.

If one has enough information about the market under investigation to assume *a priori* that prices are strongly exogenous for the parameters in the demand functions, nonstationary data series will create no problems provided that they form a long-run relationship, i.e., they are cointegrated. This can be tested using a Dickey-Fuller test as noted in Section 6.2. Note that nonstationarity of the data series only affects inference if the exogeneity assumption fails. However, this may not be the most serious problem in this case, as a failure of the exogeneity assumption when demand equations are considered may also introduce the normal simultaneity bias, making the parameter estimates inconsistent. The assumption of strong exogeneity may in this case be tested using a Hausman test (Hausman, 1978), because economic theory implies a market structure with completely elastic supply facing the agent(s) in question if the null hypothesis cannot be rejected. However, whether the data series are nonstationary matters when choosing instruments, as noted by Phillips and Hansen

[5] Theoretically, it is easy to also show that quantities can be exogenous under some assumptions (see Thurman (1986)). However, these assumptions are less plausible in most markets, although they have been advocated in some agricultural and fish markets (see e.g. Barten and Bettendorf, 1989).
[6] However, exceptions exist, e.g. LaFrance (1991).

(1990). If the exogeneity assumption fails, normal inference theory will still hold if an instrumental variables procedure is used, provided the demand equations are cointegrated and the instruments are strongly exogenous (Phillips and Hansen, 1990).

A different approach to testing for strong exogeneity might be to specify a complete Vector Auto Regression (VAR) for all the variables in the demand equations. The Johansen test (Johansen, 1988) can then be used to test both for the number of cointegration vectors in the system and to test for weak exogeneity. Provided that the long-run relationships exist and the necessary weak exogeneity assumptions hold, strong exogeneity can be tested for by testing for Granger noncausuality in the price equations.

6.4.1 Empirical Results

To validate normal inference theory in the demand system for fresh, frozen and smoked salmon estimated in Chapter 5, we must check whether the data series are stationary. If they are not, they must be cointegrated to validate normal inference. As the prices are found to be strongly exogenous, this condition is satisfied.

Using a Dickey-Fuller test (Dickey and Fuller, 1979; 1981), the data series on prices, expenditure and expenditure shares used in Chapter 5 are found to be nonstationary, as can be seen in Table 6.1. Hence, to validate normal inference theory, we must verify that it is long-run relationships that are estimated, i.e., that the variables in the share equations of the almost ideal demand system are cointegrated. This is done by estimating a static almost ideal demand system for the three product forms of salmon,

Table 6.1. Unit root tests

Variable	Test statistic	No. of lags
Fresh price	-0.045	5
Frozen price	-1.888	0
Smoked price	-1.167	1
Expenditure	1.259	4
Fresh share	-0.112	4
Frozen share	-0.553	4
Smoked share	-1.466	4

Critical value is -2.923 at a 5% level and -2.599 at a 10% level (MacKinnon, 1991).

Table 6.2. Cointegration tests

Tested Equation	Fresh salmon	Frozen salmon	Smoked salmon
Test Statistic	-4.906	-5.234	-5.732

Critical value is -4.739 at a 5% level and -4.384 at a 10% level (MacKinnon, 1991).

obtaining the residuals from each equation. Each share equation is given by equation (4) in Chapter 5. The hypothesis of cointegration is then tested by testing these residuals for stationarity using a Dickey-Fuller test. To ensure that all equations form long-run relationships (are cointegrated), the residuals from the equation for smoked salmon must also be tested for stationarity. The residuals for smoked salmon can be found either by using the residuals from the estimated system together with the adding up conditions or by reestimating the demand system with the equation for one of the other product forms deleted. Table 6.2 shows the results from the tests for stationarity of the residuals from the three equations. All equations are found to have stationary residuals, and the hypothesis of cointegration is accordingly accepted. As the prices also seem to be exogenous, normal inference theory will be valid.

6.5 Concluding Remarks

We have in this chapter addressed the issue of inference with nonstationary data in demand equations. Using results from Phillips (1991), who shows that normal inference theory will hold if the data series are cointegrated and regressors are strongly exogenous, it is argued that nonstationary data series will not create any problems when estimating demand equations, given that it is a long-run relationship which is estimated and the assumption of elastic supply holds. Actually, the requirement that the data series in the estimated demand functions must be cointegrated may be an advantage as it helps in the specification of the system when the data series are nonstationary.

REFERENCES

Anderson, G. J. and R. W. Blundell (1982) "Estimation and Hypothesis Testing in Dynamic Singular Equation Systems," *Econometrica,* 50, 1559-1571.

Anderson, G. J. and R. W. Blundell (1983) "Testing Restrictions in a Flexible Demand System: An Application to Consumers' Expenditure in Canada," *Review of Economic Studies,* 50, 397-410.

Barten, A. P. and L. J. Bettendorf (1989) "Price Formation of Fish," *European Economic Review*, 33, 1509-1525.

Berndt, E. R. and N. E. Savin (1975) "Estimation and Hypothesis Testing in Singular Equation Systems with Autoregressive Disturbances," *Econometrica,* 43, 937-958.

Berndt, E. R. and D. O. Wood (1975), "Technology, Prices, and the Derived Demand for Energy," *Review of Economics and Statistics*, 57, 259-268.

Brown, R. S. and L. R. Christensen (1981) "Estimating Elasticities of Substitution in a Model of Partial Static Equilibrium," In *Modelling and Measuring Natural Resource Substitution*, ed. E. R. Berndt and B. C. Field. Cambridge, MA: MIT Press.

Chambers, M. J. (1993) "Consumers' Demand in the Long Run: Some Evidence from UK Data," *Applied Economics*, 25, 727-733.

Christensen, L. R., D. W. Jorgenson, and L. J. Lau (1973) "Trancendental Logarithmic Production Frontiers," *Review of Economics and Statistics,* 55, 28-45.

Davidson, J. E. H., D. F. Hendry, F. Srba, and S. Yeo (1978) "Econometric Modelling of the Aggregate Time-Series Relationship Between Consumers' Expenditure and Income in the United Kingdom," *Economic Journal,* 88, 661-92.

Deaton, A. S. and J. Muellbauer (1980a) "An Almost Ideal Demand System," *American Economic Review,* 70, 312-326.

Deaton, A. S. and J. Muellbauer (1980b) *Economics and Consumer Behavior*, New York: Cambridge University Press.

Dickey, D. A. and W. A. Fuller (1979) "Distribution of the Estimators for Autoregressive Time Series with Unit Root," *Journal of the American Statistical Association,* 74, 427-431.

Dickey, D. A. and W. A. Fuller (1981) "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root," *Econometrica,* 49, 1057-1072.

Engle, R. F. and C. W. J. Granger (1987) "Co-integration and Error Correction: Representation, Estimation and Testing," *Econometrica,* 55(2), 251-276.

Engle, R. F., D. F. Hendry, and J-F. Richard (1983) "Exogeneity," *Econometrica*, 51, 277-304.

Friesen, J. (1992) "Testing Dynamic Specification of Factor Demand Equations for U.S. Manufacturing," *Review of Economics and Statistics,* 74, 240-250.

Granger, C. W. J. and P. Newbold (1986) *Forecasting Economic Time Series*, San Diego: Academic Press.

Hansen, B. E. (1992) "Efficient Estimation and Testing of Cointegration Vectors in the Presence of Deterministic Trends," *Journal of Econometrics,* 53, 87-121.

Hausman, J. A. (1978) "Specification Tests in Econometrics," *Econometrica*, 46, 1251-1271.

Johansen, S. (1988) "Statistical Analysis of Cointegration Vectors," *Journal of Economic Dynamics and Control*, 12, 231-254.

Johnson, J. A., E. H. Oksanen, M. R. Veall, and D. Fretz (1992) "Short-run and Long-run Elasticities for Canadian Consumption of Alcoholic Beverages: An Error-correction Mechanism/Cointegration Approach," *Review of Economics and Statistics*, 74, 64-74.

LaFrance, J. T. (1991) "When is Expenditure "Exogenous" in Separable Deamnd Models? ," *Western Journal of Agricultural Economics*, 16, 49-62.

MacKinnon, J. G. (1991) "Critical Values for Co-Integration Tests," In *Long-Run Economic Relationships*, ed. R. F. Engle and C. W. J. Granger. 267-276. Oxford: Oxford University Press.

Ng, S. (1995) "Testing for Homogeneity in Demand Systems when the Regressors are Nonstationary," *Journal of Applied Econometrics*, 10, 147-163.

Phillips, P. C. B. (1986) "Understanding Spurious Regressions in Econometrics," *Journal of Econometrics,* 33, 311-340.

Phillips, P. C. B. (1991) "Optimal Inference in Cointegrated Systems," *Econometrica,* 59, 283-306.

Phillips, P. C. B. and B. E. Hansen (1990) "Statistical Inference in Instrumental Variables Regressions with I(1) Processes," *Review of Economic Studies*, 57, 99-125.

Phillips, P. C. B. and M. Loretan (1991) "Estimating Long-Run Economic Equilibria," *Review of Economic Studies,* 58, 407-436.

Pollak, R. A. and T. J. Wales (1992) *Demand System Specification and Estimation,* Oxford: Oxford University Press.

Thurman, W. N. (1986) "Endogeneity Testing in a Supply and Demand Framework," *Review of Economics and Statistics*, 68, 638-646.

7: DYNAMIC ADJUSTMENT IN DEMAND EQUATIONS

7.1 Introduction

It has been recognised for a long time that dynamics might be important when considering demand equations. This is because the demand for a product may deviate from long-run equilibrium over a significant period of time. Several arguments, both of economic and statistical origin, are used to argue the importance of dynamics. The economic arguments are based in large measure on the fact that there will often be an adjustment cost when demand deviates from equilibrium. This adjustment cost can be caused by different circumstances, for instance habit formation, imperfect information or contractual obligations.[1] The statistical arguments follow from the strong dependency over time that time series data tend to exhibit, typically leading to the rejection of the hypothesis of no autocorrelation in static models.

The goal of this chapter is to focus on the dynamic adjustment of demand. This will give information on the speed of adjustment with which deviations from long-run equilibrium are corrected. This information is important if one wants to know how much, and how long it takes before the demand has fully responded to the change.

[1] It must be noted that volatility in production does not need to affect dynamics of demand. If there is perfect information and no adjustment costs, there is no reason for demand not to adjust instantaneously. However, as the adjustment cost and the cost of information may be higher in markets with volatile supply, it may be more likely that dynamics in demand is important in markets with volatile supply.

While the speed of adjustment has received some attention in the literature on factor demand and in macroeconomic work, this issue has received less attention when consumer and import demand are considered.[2] An exception is some studies where the habit formation model is used, particularly when estimating import demand (Goldstein and Khan, 1985). In these studies, a measure of how much of the adjustment takes place instantaneously is provided.

In this chapter, a single equation error correction model will be used to estimate demand equations to obtain estimates of the adjustment parameters. It will be shown that these parameters provide information of many aspects of the adjustment process following, for example, a price change. This includes how much of the adjustment takes place instantly, as well as information about how much of the adjustment has taken place after any number of periods, and how many periods it takes before the change is fully reflected in demand.

A single equation specification is used, as it is not possible to identify the adjustment parameters in any of the functional forms used for demand system specification, including the almost ideal demand system. This follows from the singularity problems caused by the expenditure share specification (Anderson and Blundell, 1983).[3] However, with a single equation demand specification, these parameters can be identified. Hence, while demand system analysis is most suitable when one wants to

[2] For studies discussing the adjustment speed in factor demand and macroeconomics, see for instance Nadiri and Rosen (1969), Davidson *et al.* (1978), Berndt, Morrison and Watkins (1981), Pindyk and Rotemberg (1983), Nickell (1986) and Asche and Salvanes (1996).

[3] This is also in contrast to the situation for factor demand specifications, where functional forms such as the generalised Leontief and the normalised quadratic allow the adjustment parameters to be identified (Asche and Salvanes, 1996).

conduct analysis based on consumer theory, other issues like dynamic adjustment need other specifications.

To illustrate the information that can be obtained from the dynamic adjustment of demand, we will estimate demand equations for fresh, frozen and smoked salmon in the European Union. These markets have been quite volatile the last decade, and a dynamic specification seems to be appropriate. This is also indicated by several earlier studies on the demand for salmon.[4] However, even though any dynamic specification implicitly or explicitly models parameters that may be interpreted as the adjustment speed for the different products, this issue has not received any attention. The emphasis has been on the elasticity estimates. However, the dynamic adjustment process is also important, since some regulation of the market has been undertaken several times, last with the implementation of minimum import prices on December 16, 1995.

The chapter is organised as follows. In Section 7.2, the data set is presented and a brief discussion of the salmon market is given. In Section 7.3, economic arguments for why demand can deviate from equilibrium for periods of time is discussed. In Section 7.4, the error correction model used to specify the demand equations is discussed, with attention on the information that is provided about the adjustment parameters. In Section 7.5 issues concerning the time series properties of the data are

[4] See Bird (1986), Bjørndal, Salvanes and Andreassen (1992) Wessells and Wilen (1993), Asche, Salvanes and Steen (1994) and Chapters 4 and 5.

discussed. In Section 7.6, empirical results are reported before some concluding remarks are given in Section 7.7.

7.2 Data and the Salmon Market

The data set used in this chapter consists of import data from the European Union's trade statistics, Eurostat. The data set contains data series with 144 observations on the value and quantity of monthly imports into the European Union of fresh, frozen and smoked salmon for the period 1981(1)-1992(12), see also Chapter 3.7.[5] Monthly data are used in this chapter as the dynamic adjustment, which is the focus of this chapter, is a short term issue, in contrast to the demand structure analysed in Chapters 4 and 5. As the salmon market in the European Union has expanded greatly over the period covered by the data set, and as the expenditure on salmon is a very small share of total income, an aggregate income measure is likely to be a poor candidate for explaining variation in the demand for the product categories of salmon considered here.[6] Total expenditure on salmon will therefore be used. This measure is comparable to the expenditure measure used in Chapters 4 and 5, and should be a good measure if the weak separability condition invoked there holds. Real values were obtained using OECD's consumer price index for the European Union.

The introduction of farmed salmon has greatly transformed the market for salmon, particularly in Europe, and the demanded quantities have increased vastly. Imports of

[5] This leaves a slight bias in the data set as national consumption is not included for the producing countries inside the Union. Inside the European Union, only the UK and Ireland produce salmon, and as their domestic consumption of salmon is small compared to the total demand in the European Union, the error this introduces in the data is likely to be small.

[6] Aggregate income measures such as gross national product or private final consumption mostly have little variation and strongly resemble a linear trend with a few kinks.

salmon by the European Union were 35,000 tons in 1981, and increased to 177,000 tons in 1992. The preferred product forms have also changed. In 1981, 29,500 tons of frozen salmon were imported, mostly from North America, while in 1992, 124,500 tons of fresh salmon were imported, mostly from European producers. Imports of frozen salmon increased to 49,000 tons in 1992, of which only about 50% was from North America. The real prices and quantities of fresh, frozen and smoked salmon imported by the European Union are graphed in Figures 7.1 and 7.2. To enable a comparison of the volatility and the strength of trends in the data series, all data series are normalised to one in January 1981. For all product forms there is an upward trend in imported quantities, and this trend is particularly strong for fresh salmon. The prices all have a downward trend.

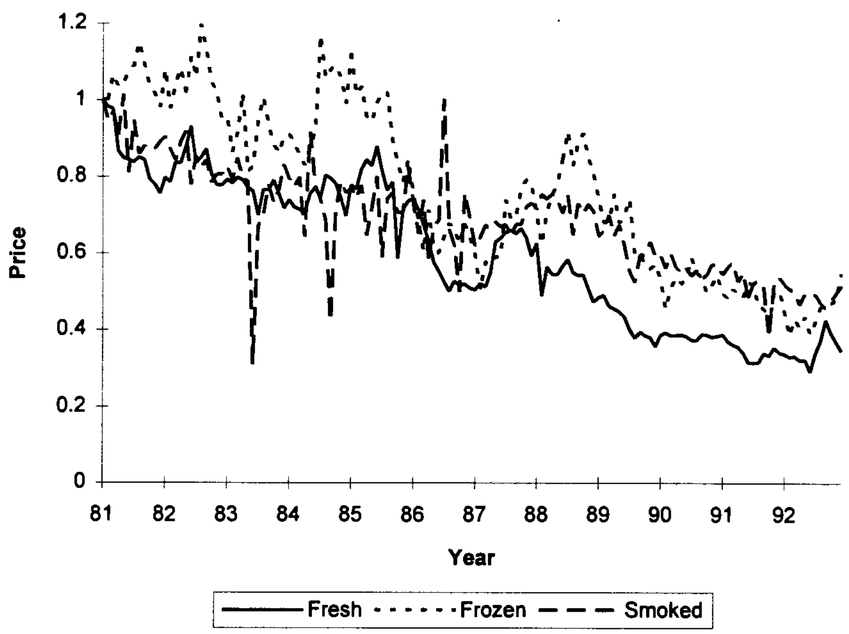


Figure 7.1. Normalised prices for salmon imports (January 1981=1)

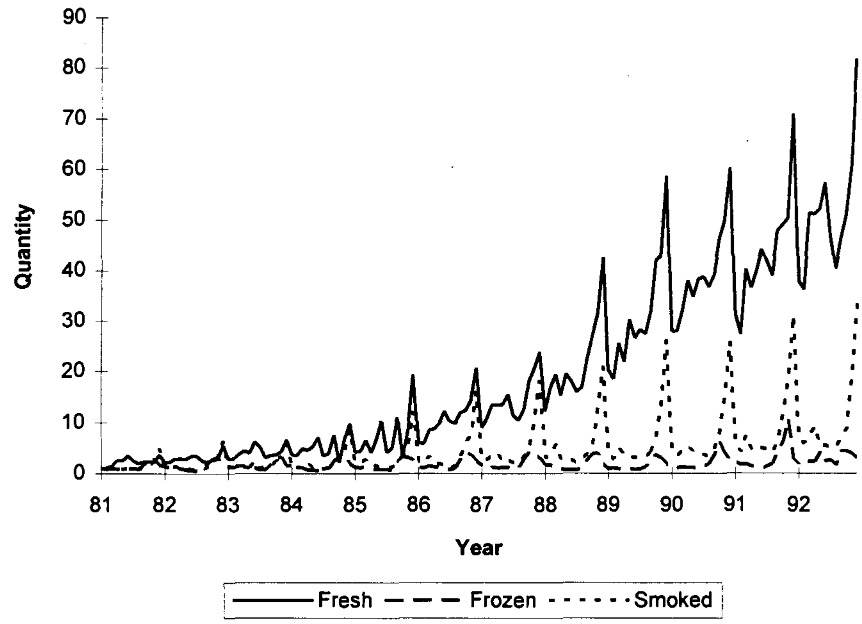


Figure 7.2. Normalised quantities for salmon imports (January 1981=1)

The imported quantities of salmon exhibit strong seasonality. This can be seen in Figure 7.2, and is evident in Figure 7.3, where average monthly consumption of the three product forms is shown for the period 1981-1992. There is a strong seasonal peak in late fall, and a weak one in spring. This is because salmon traditionally is consumed in holidays, and particularly before Christmas. Note also that imports of frozen salmon peaks earlier than fresh and smoked salmon. This is because most of the frozen salmon is used as input in the European smoking industry. However, prices do not seem to exhibit any seasonality, although they are quite volatile.

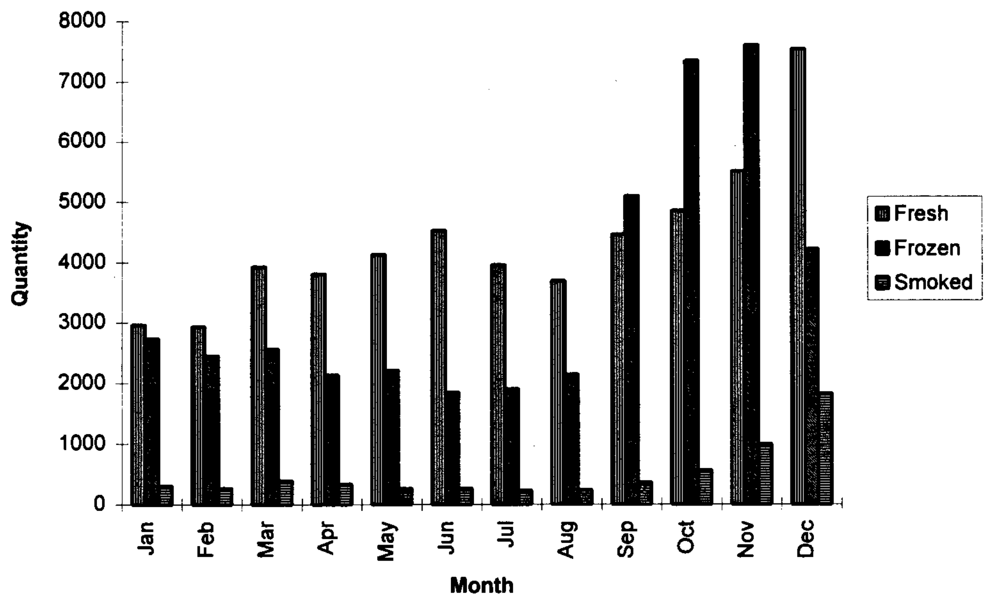


Figure 7.3. Monthly averages of salmon imports 1981-1992

Both the upward trend and the strong seasonality, and even more so the strong volatility in prices, indicate that a dynamic specification may be appropriate if the demand is to be estimated. However, strong volatility in the data series is in itself not sufficient for a dynamic specification to be necessary. Some factors, for example, adjustment costs, must also prevent demand from adjusting instantaneously to changes in prices or other factors affecting demand. This will be discussed in the next section.

7.3 Why Does Demand Deviate from Long-Run Equilibrium?

There are many explanations as to why the market for a product may deviate from the equilibrium. An early explanation in agricultural economics is the cobweb model of

Ezekiel (1938), where naive expectations on the producer side cause the supply to deviate from equilibrium. In the cobweb model the demand never deviates from equilibrium. However, there are many circumstances under which the demand for a product can deviate from long-run equilibrium, leading to a dynamic adjustment towards equilibrium. In this section economic arguments for why this might be the case are reviewed.

The first and most commonly used model to explain why demand in the short-run could deviate from equilibrium is the habit formation model proposed by Houthakker and Taylor (1966). Here, the demand for a product depends on the quantity consumed in earlier periods. Hence, the quantity consumed in earlier periods limits the possible reaction of a consumer to a changed environment (i.e., changes in prices or income). This representation can be reasonable with addictive products, when knowledge about the product does matter or when a product is used together with a durable good and the cost of changing the durable good is too large.

However, the habit formation model has a rather limited dynamic structure and allows for only one form of disequilibrium behavior. Although he only considers a habit formation model in detail, Pollak (1970) also suggest that factors like contractual obligations and imperfect information can cause demand to deviate from equilibrium. Recently, these reasons for deviations from long-run equilibrium have also gained much attention, particularly in the field of industrial organisation. Contractual obligations can limit the adjustment to a changed environment by specifying the consumption pattern of some product. Imperfect information can take many forms, and may in many cases affect the adjustment of demand to a changed environment. For instance, the consumer might find it costly to obtain all current information about a product even if it is available, and therefore base the current purchase partly on information obtained earlier. Information from earlier purchases can also be relevant in cases where information about the product may be asymmetric and the seller may vary characteristics of the product (e.g. quality) without the consumer being able to assert it before the purchase.

If the product in question is an intermediate good, the cost of adjusting the production technology to a changed environment may also cause the demand for a product to deviate from equilibrium for some time. Only when the production process has fully been altered to the new situation, will demand fully adjust to the new equilibrium.

Several of the points mentioned above may be of relevance in the European salmon market. Much of the salmon is purchased by processors. Although one would not expect large adjustment costs between different product forms of salmon, brands and origin may be important in the marketing of the product. Hence, marketing costs may affect the dynamic adjustment. There also seem to be more or less formal bindings between some exporters and importers. If these bindings are formal, they will directly be a limitation to the adjustment possibilities for the importer's demand. More commonly, the bindings are informal. However, because of considerations about quality and delivery reliability (i.e., the exporter's reputation), the adjustment possibilities may be limited. With the growth in the supply of salmon, new markets have been found. Knowledge about salmon has been found to be important for the demand in these markets, indicating that a habit formation effect may be important (Bjørndal, Salvanes and Andreassen, 1992).

7.4 Dynamic Specification

Consumer theory indicates that the demanded quantity of any product is a function of its own price, prices on substitutes and income. When estimating a dynamic demand equation with a single equation specification, one does not want to impose any further restrictions. It is then common to start with an autoregressive distributed lag model, which is the most general dynamic specification used in the literature (see e.g. Bird, 1986; Johnson *et al.*, 1992, Vaage, 1992).[7] This can be written as:

(1) $$q_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i q_{t-i} + \sum_{m=1}^{n}\sum_{j=0}^{q} \beta_{mj} p_{m,t-j} + \sum_{k=0}^{r} \gamma_k x_{t-k} + e_t$$

where q_t is the natural logarithm of quantity demanded in period t, $p_{m,t}$ is the natural logarithm of the price of product m in period t, x_t is the natural logarithm of income in period t and e_t is a white noise error term. Several more restrictive dynamic approaches are nested inside this model. These include the habit formation model, a model with autoregressive errors and a static model. For a review, see Hendry (1995, ch. 7). The long-run relationship in (1) is found by setting all the variables equal at every time t, i.e.,

(2) $$q = \frac{\alpha_0}{1-\sum_{i=1}^{p}\alpha_i} + \frac{\sum_{m=1}^{n}\sum_{j=0}^{q}\beta_{mj}}{1-\sum_{i=1}^{p}\alpha_i} p_m + \frac{\sum_{k=0}^{r}\gamma_k}{1-\sum_{i=1}^{p}\alpha_i} x + e_t = a_0 + \sum_{m=1}^{n} b_m p_{m,} + gx + e_t$$

[7] It should be noted that this approach is most common in applied macroeconomics, and is mainly based on the work of Davidson *et al.* (1978). An excellent econometric review can be found in Banerjee *et al.* (1993).

A representation of (1) that has been popular the last decade is the error correction model. This is a restriction free transformation of (1), and can be written as

$$\Delta q_t = \sum_{i=1}^{p-1} a_i \, \Delta q_{t-i} + \sum_{m=1}^{n} \sum_{j=0}^{q-1} b_{mj} \Delta p_{m,t-j} + \sum_{k=0}^{r-1} g_k \, \Delta x_{t-k} - a_P \left(q_{t-P} - a_0 - \sum_{m=1}^{n} b_m \, p_{m,t-Q} - g x_{t-R} \right) + e_t \quad (3)$$

where

$$a_i = \sum_{i=1}^{i} \alpha_i - 1, \; b_{mj} = \sum_{j=0}^{j} \beta_{mj}, \; g_k = \sum_{k=0}^{k} \gamma_k .$$

The main advantage with (3) is that the long-run relationship is explicitly shown inside the parenthesis. This specification is known as an error correction model because this term has any effect (i.e., is different from zero) only when the demand relationship deviates from equilibrium. In such specifications, the parameter $-a_P$ is interpreted as the adjustment speed for corrections of deviations from equilibrium, or disequilibrium movements. If the parameter equals unity, the adjustment is instantaneous, and a static model is an appropriate specification.[8] If the parameter equals zero, there will be no correction of disequilibrium movements. The adjustment speed parameters are mostly required to be on or between these limits (Banerjee *et al.*, 1993). This is because the adjustment will be monotonic only in this interval, and all other values induce excessive costs. Parameter values in the interval between one and two also correct disequilibrium movements, but with an oscillatory pattern, i.e., the correction overshoots the target although with declining magnitudes.[9] When the

[8] As every data set is discrete, the term instantaneous adjustment must of course be viewed relative to the frequency of the observations. For instance, with monthly data the adjustment measured by the contemporary observation covers one month, while with annual data it covers a year.

[9] One might argue that adjustment parameters between one and two are reasonable in some cases, where the correction can lead to an overshoot, as this range for the adjustment parameter implies a descending oscillatory pattern.

parameter is larger than two or less than zero, the reaction to disequilibrium movements amplifies the disequilibrium movements, oscillatory in the first case and monotonically in the last, see Hamilton (1994) or Asche and Salvanes (1996) for a further discussion.

However, the adjustment parameter may in itself be a rough measure of the adjustment, as it only delineates between instantaneous adjustment and how much of the adjustment takes place in later periods (the effect of the lagged quantities, $\Sigma_i \alpha_i$, give the adjustment in later periods). Information on how much of the impact of a deviation from equilibrium that is corrected in each period, may be obtained using what may be called each period's adjustment parameter or the dynamic multiplier, α_i.[10] While the information contained in these parameters is mostly ignored in the demand literature, it is interpreted in the time series literature (see e.g. Hamilton, 1994). The dynamic multiplier can be interpreted as the adjustment that takes place *i* periods after the disequilibrium movement. Note that it is these parameters that add up to the part of the adjustment parameter that does not adjust instantaneously, i.e., $-a_P = 1-\Sigma_i \alpha_i$. By considering the dynamic multiplier in each period, we will be able to say how much of the adjustment takes place in every period, and by adding these parameters to the adjustment parameter for the desired number of periods, we can say how much of the adjustment has taken place after any number of periods. Thus for $n<P$, $-a_P+\sum_{i=1}^{n}\alpha_i = 1-\sum_{i=n+1}^{P}\alpha_i = -a_P + a_n + 1$ can be interpreted as the

[10] The term dynamic multiplier is used in the univariate time series literature, see e.g. Hamilton (1994, p. 3).

adjustment that has taken place after *n* periods. Note that $-a_P + \sum_{i=1}^{P} \alpha_i = 1$, i.e., after *P* periods all the adjustment has taken place.

The adjustment parameter and the dynamic multipliers can be obtained from both an autoregressive distributed lag model and an error correction model. In the autoregressive distributed lag model the dynamic multipliers are estimated directly and the adjustment parameter must be inferred from the dynamic multipliers. In the error correction model the adjustment parameter is estimated directly, and the dynamic multipliers must be inferred from the estimated a_i parameters. Note also that nonstationarity and cointegration have not been mentioned yet. Even if error correction models fit hand in glove with nonstationary but cointegrated data series, the model works just as well with stationary data series as it is just a restriction free transformation of an autoregressive distributed lag model.

7.5 Integration and Cointegration

It is now widely recognised that most economic data series tend to be nonstationary, and Figures 7.1 and 7.2 indicate that this may also be the case for the prices and quantities used here. Before estimating the demand equations, the time series properties of the data series is investigated. This is done using a Dickey-Fuller test (Dickey and Fuller, 1979; 1981). The results are reported in Table 7.1, and all the data series seem to be nonstationary.[11]

[11] All estimation and tests in this chapter were done with the econometric software package Shazam (White, 1978).

Table 7.1. Unit root tests

Variable	Test statistic	No. of lags
Fresh price	-1.062	1
Frozen price	-1.361	1
Smoked price	-0.808	1
Fresh quantity	-1.463	11
Frozen quantity	0.601	11
Smoked quantity	-0.133	11
Income	0.167	11

Critical value is -2.881 at a 5% level and -2.577 at a 10% level (MacKinnon, 1991).

As our data series are nonstationary, it must be confirmed that the data series in each of our demand equations form a long-run relationship. This is done by testing if they are cointegrated. Cointegration is a key concept when dealing with nonstationary data series because the existence of a cointegration vector is a necessary condition for nonstationary variables to form a long-run relationship (Engle and Granger, 1987). A regression on nonstationary data series without a cointegration relationship will produce a spurious relationship (Granger and Newbold, 1986; Phillips, 1986). However, in the special case when two or more nonstationary data series integrated of the same order form a long-run relationship, i.e., they move together through time, a regression on these variables will produce stationary residuals. In this case the variables are said to be cointegrated. Whether the data series in our demand equations are cointegrated can be tested by testing the residuals from a static regression on the levels of the data series in the demand equations (equation (4)) for stationarity. This can also be done by a Dickey-Fuller test. The results in our case are reported in Table 7.2, and the data series in all demand equations seem to be cointegrated.

Table 7.2. Long-run estimates

Variable		Equation	
	Fresh	Frozen	Smoked
Fresh price	-0.594	0.495	-0.106
Frozen price	0.070	-1.179	-0.513
Smoked price	0.111	-0.508	-0.085
Income	0.372	1.326	1.390
Trend	0.019	-0.012	-0.001
Constant	3.028	-2.184	-4.370
R^2	0.949	0.813	0.876
Cointegration test	-9.624	-9.392	-9.302

Critical value for the cointegration tests is -4.531 at a 5% level and -4.225 at a 10% level (MacKinnon, 1991).

7.6 Empirical Results

To estimate the demand equations for fresh, frozen and smoked salmon in an error correction model, the two-step estimator of Engle and Granger (1987) is used since the data series are nonstationary but cointegrated.[12] The advantage with the two-step estimator is that even though (3) is nonlinear, all the parameters can be estimated with

[12] As the variables in the short-run dynamics are differenced, they are stationary and their parameters have the usual property of root-*T* convergence. However, the parameters in the long-run relationship converge at the rate $O(T)$, and are super consistent.

ordinary least squares. In the first step the long-run relationship is estimated in a static regression on the levels of the variables, i.e.,

$$(4) \qquad q_t = a_0 + \sum_{i=F,Z,S} a_i \, p_{i,t} + g x_t + e_t \,,$$

where F indicates fresh, Z frozen and S smoked salmon. Engle and Granger show that these estimates are super consistent, but normal inference theory does not apply. The results are reported in Table 7.2.[13] With the exception of the parameter for fresh salmon in the equation for smoked salmon that indicates that these two products are complements, the signs on the parameters are all similar to earlier studies.[14] However, the own-price and income effects for fresh salmon are somewhat weaker than what is normally reported, while the same responses are stronger for frozen salmon. Relatively high R^2 values also support the hypothesis of cointegration in all equations.

The second step is to estimate the short-run dynamics with a specification like (3), using the parameters obtained in step one for the long-run relationship. Several earlier studies have indicated that the demand for salmon has a seasonal pattern. To control for seasonality, seasonal dummies, d_i, with January as the base period are included. To include all relevant information, a sufficently large number of lags must be chosen. We first tried with a model that covered a year, i.e., eleven lags are specified. The estimated equation can then be written as:

[13] All the specification issues related to derived demand and simultaneity discussed in Chapter 5.3 do also apply here. As the discussion would be similar, it is referred to the discussion in that section.

[14] There are a number of studies considering the demand for fresh salmon or an aggregate of salmon, see Bird (1986), Herrmann and Lin (1988), Bjørndal, Salvanes and Andreassen (1992), Herrmann, Mittelhammer and Lin (1992; 1993), DeVoretz and Salvanes (1993), Bjørndal, Gordon and Salvanes (1994). Recently the demand for different product forms of salmon (also fresh, frozen and smoked) have been estimated in demand systems, see Wessells and Wilen (1993; 1994), Asche, Salvanes and Steen (1994) and Chapters 4 and 5 in this dissertation.

(5) $$\Delta q_t = \sum_{i=1}^{10} a_i \, \Delta q_{t-i} + \sum_{m=F,Z,S} \sum_{j=0}^{10} b_{mj} \Delta p_{m,t-j} + \sum_{k=0}^{10} g_k \, \Delta x_{t-k} + \sum_{i=2}^{12} D_i d_i - a_P \left(ECM_{t-11} \right) + e_t ,$$

where *ECM* is the estimated long-run relationship from equation (4). The parameters from these regressions are reported in Tables 7.3, 7.4 and 7.5. Higher lags do not seem to incorporate much information as the hypothesis of no autocorrelation can be rejected with this specification. Moreover, as many of the parameters on the higher lags seem to capture relevant information, it is not tried to simplify the dynamic structures. Also note the seasonal peaks in late spring and before Christmas for fresh and smoked salmon. For frozen salmon the peaks are somewhat earlier. This is reasonable as frozen salmon mostly is used as an input factor by the European smoking industry.

To facilitate the discussion of the dynamics, the adjustment parameters and dynamic multipliers are shown in Table 7.6, and the cumulative adjustment, i.e., the share of the adjustment that has taken place after *n* periods, is shown in Table 7.7. The cumulative adjustment is also graphed in Figure 7.4. The adjustment speed of all product forms is slow as the quickest, fresh salmon, has an adjustment parameter of 0.121. Frozen salmon has a adjustment parameter of 0.106 and smoked salmon of 0.018. Even though the instantaneous adjustment is slow, most of the adjustment takes place over the next three months. For all product categories, more than 60% of the adjustment has taken place three periods after the disequilibrium movement. In the next three periods the adjustment is slow and in fact negative in some periods. The remaining adjustment takes place over the last few periods.

Table 7.3. Short-run estimates for fresh salmon

Variable	Estimate	St. Dev	Variable	Estimate	St. Dev
a1	-0.813*	(0.122)	bsmoked2	-0.013	(0.215)
a2	-0.719*	(0.150)	bsmoked3	0.204	(0.234)
a3	-0.412*	(0.152)	bsmoked4	0.249	(0.247)
a4	-0.463*	(0.149)	bsmoked5	0.335	(0.249)
a5	-0.418*	(0.160)	bsmoked6	0.085	(0.236)
a6	-0.415*	(0.163)	bsmoked7	0.164	(0.215)
a7	-0.502*	(0.170)	bsmoked8	0.205	(0.190)
a8	-0.553*	(0.188)	bsmoked9	0.040	(0.167)
a9	-0.372*	(0.195)	bsmoked10	0.138	(0.143)
a10	-0.281	(0.188)	g0	0.487*	(0.151)
bfresh0	-0.039	(0.330)	g1	-0.001	(0.180)
bfresh1	-0.037	(0.329)	g2	-0.094	(0.193)
bfresh2	-0.487	(0.322)	g3	0.201	(0.208)
bfresh3	-0.666*	(0.325)	g4	0.302	(0.222)
bfresh4	-0.688*	(0.327)	g5	0.223	(0.232)
bfresh5	-0.178	(0.343)	g6	0.289	(0.230)
bfresh6	-0.184	(0.350)	g7	0.205	(0.226)
bfresh7	-0.245	(0.354)	g8	0.400**	(0.215)
bfresh8	-0.506	(0.360)	g9	0.245	(0.203)
bfresh9	-0.505	(0.360)	g10	0.344**	(0.172)
bfresh10	-0.145	(0.361)	aP	-0.121	(0.172)
bfrozen0	-0.419	(0.309)	D2	-0.401**	(0.202)
bfrozen1	-0.129	(0.337)	D3	-0.406	(0.290)
bfrozen2	-0.360	(0.337)	D4	0.130	(0.319)
bfrozen3	0.114	(0.330)	D5	0.231	(0.315)
bfrozen4	0.297	(0.320)	D6	0.042	(0.303)
bfrozen5	0.191	(0.314)	D7	0.064	(0.296)
bfrozen6	0.371	(0.310)	D8	-0.131	(0.316)
bfrozen7	0.249	(0.304)	D9	-0.074	(0.348)
bfrozen8	-0.571**	(0.307)	D10	-0.074	(0.338)
bfrozen9	-0.889*	(0.312)	D11	0.413	(0.304)
bfrozen10	-0.649*	(0.319)	D12	0.534*	(0.206)
bsmoked0	-0.226	(0.157)	a0	0.063	(0.214)
bsmoked1	0.060	(0.190)			
R^2	0.922				

*indicates significant at a 5% level and ** indicates significant at a 10% level.

Table 7.4. Short-run estimates for frozen salmon

Variable	Estimate	St. Dev	Variable	Estimate	St. Dev
a1	-0.571*	(0.124)	bsmoked2	0.097	(0.214)
a2	-0.466*	(0.147)	bsmoked3	0.000	(0.242)
a3	-0.442*	(0.155)	bsmoked4	-0.046	(0.246)
a4	-0.333*	(0.169)	bsmoked5	-0.145	(0.245)
a5	-0.457*	(0.176)	bsmoked6	-0.057	(0.238)
a6	-0.403*	(0.192)	bsmoked7	-0.120	(0.218)
a7	-0.258	(0.203)	bsmoked8	-0.083	(0.200)
a8	-0.215	(0.206)	bsmoked9	-0.278	(0.184)
a9	-0.244	(0.209)	bsmoked10	-0.200	(0.165)
a10	-0.173	(0.213)	g0	1.230*	(0.149)
bfresh0	-0.113	(0.321)	g1	0.955*	(0.230)
bfresh1	-0.169	(0.317)	g2	0.949*	(0.271)
bfresh2	0.071	(0.319)	g3	0.709*	(0.299)
bfresh3	0.398	(0.315)	g4	0.548**	(0.310)
bfresh4	0.170	(0.318)	g5	0.500**	(0.311)
bfresh5	-0.470	(0.336)	g6	0.630*	(0.312)
bfresh6	-0.102	(0.347)	g7	0.617**	(0.322)
bfresh7	0.050	(0.356)	g8	0.484	(0.327)
bfresh8	0.306	(0.361)	g9	0.250	(0.319)
bfresh9	0.220	(0.354)	g10	0.222	(0.289)
bfresh10	-0.019	(0.337)	aP	-0.106	(0.184)
bfrozen0	-0.693*	(0.282)	D2	0.264	(0.225)
bfrozen1	-0.704*	(0.326)	D3	0.025	(0.309)
bfrozen2	-0.390	(0.345)	D4	-0.239	(0.325)
bfrozen3	-0.800*	(0.345)	D5	-0.542**	(0.338)
bfrozen4	-0.132	(0.356)	D6	-0.375	(0.347)
bfrozen5	0.212	(0.360)	D7	0.107	(0.324)
bfrozen6	-0.133	(0.347)	D8	0.302	(0.339)
bfrozen7	-0.616**	(0.342)	D9	0.212	(0.374)
bfrozen8	-0.652**	(0.349)	D10	-0.016	(0.372)
bfrozen9	-0.420	(0.369)	D11	-0.420	(0.303)
bfrozen10	-0.254	(0.378)	D12	-0.893*	(0.213)
bsmoked0	-0.144	(0.157)	a0	0.070	(0.225)
bsmoked1	-0.191	(0.189)			
R^2	0.934				

*indicates significant at a 5% level and ** indicates significant at a 10% level.

Table 7.5. Short-run estimates for smoked salmon

Variable	Estimate	St. Dev	Variable	Estimate	St. Dev
a1	-0.717*	(0.121)	bsmoked2	-0.806*	(0.213)
a2	-0.638*	(0.133)	bsmoked3	-0.691*	(0.236)
a3	-0.417*	(0.143)	bsmoked4	-0.627*	(0.239)
a4	-0.468*	(0.142)	bsmoked5	-0.490*	(0.242)
a5	-0.445*	(0.146)	bsmoked6	-0.676*	(0.228)
a6	-0.337*	(0.150)	bsmoked7	-0.069	(0.218)
a7	-0.195	(0.155)	bsmoked8	-0.226	(0.201)
a8	-0.042	(0.161)	bsmoked9	0.520*	(0.175)
a9	0.009	(0.170)	bsmoked10	0.028	(0.153)
a10	0.077	(0.168)	g0	0.473*	(0.109)
bfresh0	0.240	(0.259)	g1	0.205	(0.147)
bfresh1	-0.068	(0.251)	g2	0.152	(0.157)
bfresh2	0.155	(0.250)	g3	0.109	(0.165)
bfresh3	-0.303	(0.250)	g4	0.201	(0.182)
bfresh4	-0.399**	(0.248)	g5	0.366	(0.208)
bfresh5	0.019	(0.252)	g6	0.076	(0.224)
bfresh6	-0.402	(0.266)	g7	0.105	(0.225)
bfresh7	-0.053	(0.271)	g8	-0.180	(0.226)
bfresh8	0.200	(0.270)	g9	0.089	(0.227)
bfresh9	0.527**	(0.275)	g10	0.022	(0.228)
bfresh10	0.244	(0.259)	aP	-0.018	(0.162)
bfrozen0	-0.320	(0.214)	D2	-0.135	(0.244)
bfrozen1	0.199	(0.238)	D3	0.312	(0.328)
bfrozen2	0.186	(0.243)	D4	0.303	(0.329)
bfrozen3	0.207	(0.248)	D5	0.228	(0.350)
bfrozen4	0.438**	(0.239)	D6	-0.230	(0.355)
bfrozen5	-0.117	(0.246)	D7	-0.392	(0.340)
bfrozen6	0.168	(0.252)	D8	-0.348	(0.362)
bfrozen7	0.172	(0.242)	D9	0.011	(0.373)
bfrozen8	-0.100	(0.238)	D10	0.461	(0.354)
bfrozen9	-0.408**	(0.245)	D11	1.216*	(0.313)
bfrozen10	-0.675*	(0.248)	D12	1.414*	(0.170)
bsmoked0	-0.896*	(0.121)	a0	-0.210	(0.234)
bsmoked1	-0.784*	(0.179)			
R^2	0.982				

*indicates significant at a 5% level and ** indicates significant at a 10% level.

Note that for smoked salmon the adjustment overshoots in two periods. These features are hard to explain, as they induce excessive adjustment costs. However, the overshoots are not significant, and the magnitude of the overshoots is small. Hence, it is likely that the overshoots are caused by noise in the data series, although also functional misspecification may cause the problem.

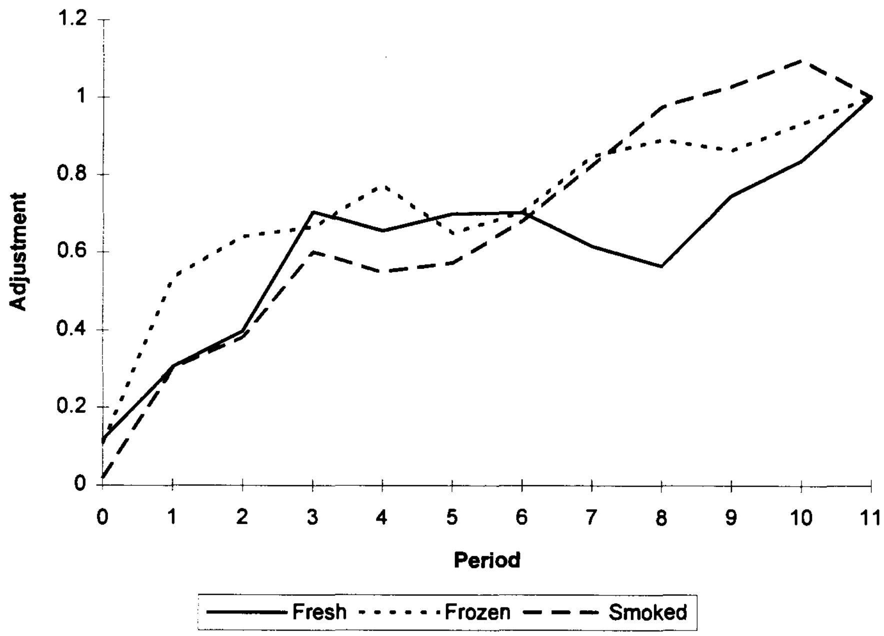


Figure 7.4. Cumulative adjustment

Table 7.6. Adjustment parameters

Parameter	Equation		
	Fresh salmon	Frozen salmon	Smoked salmon
a_P	0.121	0.106	0.018
α_1	0.187	0.429	0.283
α_2	0.094	0.105	0.080
α_3	0.307	0.024	0.220
α_4	-0.050	0.108	-0.051
α_5	0.044	-0.123	0.023
α_6	0.003	0.053	0.108
α_7	-0.087	0.145	0.142
α_8	-0.050	0.043	0.153
α_9	0.181	-0.028	0.051
α_{10}	0.091	0.070	0.068
α_{11}	0.163	0.067	-0.095

Table 7.7. Cumulative adjustment

Period	Equation		
	Fresh salmon	Frozen salmon	Smoked salmon
0	0.117	0.107	0.018
1	0.304	0.536	0.301
2	0.398	0.641	0.381
3	0.705	0.665	0.601
4	0.655	0.773	0.550
5	0.699	0.650	0.573
6	0.702	0.703	0.681
7	0.615	0.848	0.823
8	0.565	0.891	0.976
9	0.746	0.863	1.027
10	0.837	0.933	1.095
11	1.000	1.000	1.000

7.7 Concluding remarks

In this chapter, the emphasis was on obtaining information about the dynamic adjustment of demand. Therefore, single equation error correction specifications were used to specify the demand equations. It was shown that the parameters in the error correction model provide information about how much of the effect of a price (or expenditure) change is reflected instantaneously in the demand, and how many periods it takes for demand to fully adjust to price changes. The parameters also provide information on how much of the adjustment has taken place after any number of periods.

The empirical results indicate that a dynamic specification is important for the three product forms of salmon considered here. Only around 10% of the adjustment of a disequilibrium movement takes place instantaneously. However, more than 60% of the adjustment takes place after three periods for all the product forms. Still, it takes a whole year before the change is fully reflected in demand. That there is a significant time of adjustment before demand fully reflect changes in prices and other factors, indicates that it is possible to affect the market by regulations in the short term by changing the equilibrium.

REFERENCES

Anderson, G. J. and R. W. Blundell (1983) "Testing Restrictions in a Flexible Demand System: An Application to Consumers' Expenditure in Canada," *Review of Economic Studies,* 50, 397-410.

Asche, F. and K. G. Salvanes (1996) "Dynamic Factor Demand Systems and the Adjustment Speed Towards Equilibrium," *Canadian Journal of Economics*, 29, S576-S581.

Asche, F., K. G. Salvanes, and F. Steen (1994) "Market Delineation and Demand Structure," Centre for Research in Economics and Business Administration. SNF-Working Paper no. 106/94.

Banerjee, A., J. Dolado, J. W. Galbraith, and D. F. Hendry (1993) *Co-integration, Error Correction, and the Econometric Analysis of Non-stationary Data*, Oxford: Oxford University Press.

Berndt, E. R., C. J. Morrison, and G. C. Watkins (1981) "Dynamic Models of Energy Demand: An Assesment and Comparison," In *Modeling and Measuring Natural Resource Substitution*, ed. E. R. Berndt and B. C. Field. 259-289. Cambridge: MIT Press.

Bird, P. (1986) "Econometric Estimation of World Salmon Demand," *Marine Resource Economics,* 3, 169-182.

Bjørndal, T., D. V. Gordon, and K. G. Salvanes (1994) "Elasticity Estimates of Farmed Salmon Demand in Spain and Italy," *Empirical Economics,* 4, 419-428.

Bjørndal, T., K. G. Salvanes, and J. H. Andreassen (1992) "The Demand for Salmon in France: the Effects of Marketing and Structural Change," *Applied Economics,* 24, 1027-1034.

Davidson, J. E. H., D. F. Hendry, F. Srba, and S. Yeo (1978) "Econometric Modelling of the Aggregate Time-Series Relationship Between Consumers' Expenditure and Income in the United Kingdom," *Economic Journal,* 88, 661-92.

DeVoretz, D. J. and K. G. Salvanes (1993) "Market Structure for Farmed Salmon," *American Journal of Agricultural Economics,* 75, 227-233.

Dickey, D. A. and W. A. Fuller (1979) "Distribution of the Estimators for Autoregressive Time Series with Unit Root," *Journal of the American Statistical Association,* 74, 427-431.

Dickey, D. A. and W. A. Fuller (1981) "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root," *Econometrica,* 49, 1057-1072.

Engle, R. F. and C. W. J. Granger (1987) "Co-integration and Error Correction: Representation, Estimation and Testing," *Econometrica,* 55(2), 251-276.

Ezekiel, M. (1938) "The Cobweb Theorem," *Quarterly Journal of Economics,* 52, 255-280.

Goldstein, M. and Khan, M. S. (1985), "Income and Price Effects in Foregin Trade," In *Handbook of International Economics*, ed. R. W. Jones and P. B. Kenen, 1041-1105. New York: Elsevier.

Granger, C. W. J. and P. Newbold (1986) *Forecasting Economic Time Series*, San Diego: Academic Press.

Hamilton, J. D. (1994) *Time Series Analysis*, Princeton, NJ: Princeton.

Hendry, D. F. (1995) *Dynamic Econometrics*, Oxford: Oxford University Press.

Herrmann, M., R. C. Mittelhammer, and B. H. Lin (1992) "Applying Almon-Type Polynomials in Modelling Seasonality of the Japanese Demand for Salmon," *Marine Resource Economics,* 7, 3-13.

Herrmann, M. L. and B. H. Lin (1988) "The Demand and Supply of Norwegian Atlantic Salmon in the United States and the European Community," *Canadian Journal of Agricultural Economics,* 38, 459-471.

Herrmann, M. L., R. C. Mittelhammer, and B. H. Lin (1993) "Import Demand for Norwegian Farmed Atlantic Salmon and Wild Pacific Salmon in North America, Japan and the EC," *Canadian Journal of Agricultural Economics,* 41, 111-125.

Houthakker, H. S. and L. D. Taylor (1966) *Consumer Demand in the United States: Analysis and Projections*, Cambridge, MA: Harvard University Press.

Johnson, J. A., E. H. Oksanen, M. R. Veall, and D. Fretz (1992) "Short-run and Long-run Elasticities for Canadian Consumption of Alcoholic Beverages: An Error-correction Mechanism/Cointegration Approach," *Review of Economics and Statistics,* 74, 64-74.

MacKinnon, J. G. (1991) "Critical Values for Co-Integration Tests," In *Long-Run Economic Relationships*, ed. R. F. Engle and C. W. J. Granger. 267-276. Oxford: Oxford University Press.

Nadiri, M. I. and S. Rosen (1969) "Interrelated Factor Demand Functions," *American Economic Review,* 59, 457-471.

Nickell, S. J. (1986) "Dynamic Models of Labour Demand," In *Handbook of Labor Economics*, ed. O. Ashenfelter and R. Layard. 473-522. Amsterdam: North-Holland.

Phillips, P. C. B. (1986) "Understanding Spurious Regressions in Econometrics," *Journal of Econometrics,* 33, 311-340.

Pindyck, R. S. and J. J. Rotemberg (1983) "Dynamic Factor Demand and the Effects of Energy Price Shocks," *American Economic Review,* 73, 1066-1079.

Pollak, R. A. (1970) "Habit Formation and Dynamic Demand Functions," *Journal of Political Economy,* 78, 745-763.

Vaage, K. (1992) "The Dynamics of Residential Electricity Demand: Empirical Evidence from Norway. SNF Working Paper No. 134/1992."

Wessells, C. R. and J. E. Wilen (1993) "Economic Analysis of Japanese Household Demand for Salmon," *Journal of the World Aquaculture Society,* 24, 361-378.

Wessells, C. R. and J. E. Wilen (1994) "Seasonal Patterns and Regional Preferences in Japanese Household Demand for Seafood," *Canadian Journal of Agricultural Economics,* 42, 87-103.

White, K. J. (1978) "A General Computer Program for Econometric Methods-SHAZAM," *Econometrica*, 46, 239-240.

8: SUMMARY AND CONCLUSIONS

8.1 Introduction

This dissertation has focused on different dynamic specifications of demand equations. Emphasis has been on theoretically consistent demand specifications, but a more data oriented approach has also been considered. The different demand equation specifications have been utilised to investigate the demand structure in the salmon market in the European Union. In this chapter, a summary of the methodologies used and the results obtained is given. Some remarks on the policy implications of the results are also offered.

Detailed reviews of some issues relevant to this dissertation were given in Chapters 2 and 3. In Chapter 2, the necessary conditions for demand equations to be theoretically consistent were reviewed together with more practical issues in demand equation specification, such as separability, functional forms, simultaneity and derived demand. In Chapter 3, the salmon market, with emphasis on the European Union, was discussed. A brief review of earlier studies of the demand for salmon and a thorough discussion of the data sets were also provided.

This chapter will be organised as follows. In the next Section, the methodologies used will be summarised and commented upon. In Section 8.3, the empirical results are summarised, while some policy implications are discussed in Section 8.4. In Section 8.5, some suggestions for future research of salmon markets are offered.

8.2 Methodology

In Chapter 4, the fully modified least squares (FMLS) estimator of Phillips and Hansen (1990) was used to estimate the demand for fresh, frozen and smoked salmon, using the almost ideal demand system of Deaton and Muellbauer (1980). The fully modified least squares estimator has previously been used by Chambers (1993) when estimating an almost ideal demand system. However, his approach was expanded by allowing for deterministic components in the demand system, using the results of Hansen (1992). When the data series are nonstationary, there are two main advantages with the fully modified least squares estimator compared to ordinary least squares or seemingly unrelated regressions. First, when using the fully modified least squares estimator, normal inference theory applies even when the data series used are nonstationary, provided that they form a long-run relationship, i.e., are cointegrated. This was indeed the case in this analysis as the data series, in common with most economic data series, were found to be nonstationary, but cointegrated. Also, as a heteroskedasticity and autocorrelation consistent estimate of the covariance matrix is used, autocorrelation will not cause problems by giving inefficient estimators.

However, some caveats should be noted with the fully modified least squares estimator. Although it is asymptotically equivalent to an ordinary least squares or seemingly unrelated regression estimator when there are no problems with nonstationary components in the distribution of the estimators and no autocorrelation, the ordinary least squares or seemingly unrelated regression estimator are more efficient in limited samples (Davidson and MacKinnon, 1993). Moreover, when using the heteroskedasticity and autocorrelation consistent covariance matrix, one implicitly assumes that the only dynamics present are autoregressive errors. If the true dynamics are more general, the use of a heteroskedasticity and autocorrelation consistent covariance matrix is not sufficient to solve the problem of dynamic misspecification. A more general dynamic structure is then needed. A third problem is that there are no misspecification tests that can be used together with the fully modified least squares estimator. Hence, it is difficult to evaluate the performance of the estimated model.

In Chapter 5, a parametric specification of the dynamics is used when estimating the demand for fresh, frozen and smoked salmon. Here also, the almost ideal demand system of Deaton and Muellbauer (1980) is used to specify the demand system. The dynamic specification is based on the work of Anderson and Blundell (1982; 1983; 1984). However, by using the Bewley transformation of Wickens and Breusch (1988) of an error correction model, it was possible to obtain a linear specification of the dynamic structure.

By using a parametric specification of the dynamics, normal misspecification tests can be utilised. However, there are some problems using the Durbin-Watson test, which is commonly used when testing for autocorrelation in demand systems. The test is an equation by equation test, and is not invariant to which equation is deleted in a singular demand system. As well, the test does not take cross equation autocorrelation into account. It is shown that these problems can be avoided by using the LM test of

Godfrey (1981). This test was suggested in a simultaneous equation context, but also applies in the seemingly unrelated regression case.

The importance of allowing a general dynamic specification can be seen in several ways. The hypothesis of no autocorrelation and the homogeneity and symmetry restrictions implied by consumer theory are rejected in the static model, and provide evidence against this specification. The rejection of the homogeneity and symmetry restrictions in the model in Chapter 4 also provides evidence against a model with autoregressive errors. This further emphasises the drawback of not being able to use misspecification tests, such as a test for autocorrelation, when using the fully modified least squares estimator. Attention to the dynamic structure is important, as is seen by noting that the homogeneity and symmetry restrictions implied by consumer theory cannot be rejected when using the most general dynamic specification. This corresponds with the results reported in other studies using an error correction representation to specify the dynamics in a demand system (Anderson and Blundell, 1983; 1984; Veall and Zimmermann, 1986).

There is, however, a major problem with a parametric specification of the dynamics in applied work. The number of observations available is often limited, and an additional lag in the dynamic structure consumes many degrees of freedom. Hence, when estimating a dynamic demand system with a parametric specification of the dynamics, there is often a trade-off between the number of lags and the number of goods one may include in the system. This trade-off is what Hendry (1995, p. 313) refers to as "the curse of dimensionality". Omitting a lag in the dynamic specification can create problems with inference and also leads to inconsistent parameter estimates. However, excluding a good that belongs to the system violates the true weak separability condition, and may, together with the adding up condition, lead to incorrect results. This can most easily be seen by noting that the adding up condition forces at least one expenditure elasticity to be elastic if at least one good is inelastic. If, for instance, one excludes the only good in the true system that is expenditure elastic, at least one of the other goods in the system will be forced to be elastic by the adding up condition. This problem may be less serious if the estimated demand system includes both truly elastic and truly inelastic goods.

In Chapter 6, the issue of inference in demand equations when the data series are nonstationary is addressed. Normal inference theory is in general not valid in regressions on nonstationary data series. However, when the data series form a long-run relationship, i.e., are cointegrated, the distribution of the estimators is a linear combination of a compounded normal and a unit root distribution. In this case, normal inference theory will apply if the unit root component is controlled for, as with the fully modified least squares estimator, or when the regressors are strongly exogenous, as the unit root component in the distribution of the estimators disappears in this case (Phillips, 1991). When estimating demand equations, economic theory often indicates that the regressors are strongly exogenous. This will be the case when the supply is completely elastic for the agents in question. This holds for example when the goods are supplied competitively or when the demand analysed is small compared to the market. As price and quantity of a good must form a long-run relationship for the analysis to make sense, these market structures also validate normal inference theory when estimating demand equations when the data series are nonstationary.

While demand system estimation is most suitable when one wants to conduct analysis based on consumer theory, other issues may be better analysed with other specifications. In dynamic demand systems with expenditure share equations, the parameters measuring the adjustment speed towards equilibrium after a price or expenditure change are unidentified. However, with a single equation demand specification these parameters can be identified. In Chapter 7, a single equation error correction model is used to analyse the adjustment after disequilibrium movements. It is shown that this model provides information on how much of the adjustment is instantaneous, how much of the adjustment takes place in each period and how long it takes to completely adjust to a change in price or expenditure.

8.3 Empirical Results

The different approaches to estimation of demand equations have all been used to analyse the demand structure in the salmon market in the European Union. This is done by estimating demand for fresh, frozen and smoked salmon. The empirical results give more information about the demand for salmon than earlier studies, as more product forms are considered. In most studies, only fresh salmon or an aggregate of all salmon are considered.[1] Exceptions are Wessells and Wilen (1993; 1994), who consider fresh and salted salmon in a system with many seafood products in Japan,

[1] See DeVoretz (1982), Bird (1986), Herrmann and Lin (1988), Bjørndal, Salvanes and Andreassen (1992), Herrmann, Mittelhammer and Lin (1992; 1993), Bjørndal, Gordon and Singh (1993), DeVoretz and Salvanes (1993) and Bjørndal, Gordon and Salvanes (1994).

and Asche, Salvanes and Steen (1994), who consider fresh and frozen salmon in the European Union.[2] To the author's knowledge, no one has previously estimated demand for smoked salmon. Hence, the empirical results in this dissertation hopefully add to the knowledge about the demand for frozen and smoked salmon and the relationships between the three product forms, which previously has been limited.

When discussing the elasticities, only those obtained from the theoretically consistent specifications in Chapters 4 and 5 are considered. To facilitate comparison of the results from these two chapters, the elasticities are reproduced in tables 8.1, 8.2, 8.3 and 8.4. The empirical results indicate that fresh and frozen salmon and fresh and smoked salmon are substitutes. This is particularly clear when considering the compensated cross-price elasticities, which are all significantly different from zero. The uncompensated elasticities, where the expenditure effect is taken into account, also indicate substitutes, although with lower magnitudes. One explanation for this may be the strong increase in demand for all three product forms over the period studied. The cross-price elasticities between frozen and smoked salmon indicate complements. While initially surprising, this result seems reasonable when the fact that frozen salmon is mostly imported as an input factor in the European smoking industry is taken into consideration.

[2] Kabir and Ridler (1984) estimate demand equations for both fresh and frozen salmon. However, their study came too early to capture the effect of the salmon aquaculture industry.

Table 8.1. Uncompensated elasticities from Chapter 4[a,b]

	Fresh	Frozen	Smoked	Expenditure
Fresh	-1.725*	0.135	0.235**	1.355*
	(0.2429)	(0.1989)	(0.1695)	(0.1331)
Frozen	0.567*	-0.277	-0.449*	0.158*
	(0.1498)	(0.2301)	(0.1771)	(0.1449)
Smoked	0.197	-1.491*	-0.596*	1.891*
	(0.3382)	(0.3213)	(0.2547)	(0.1005)

* indicates significant at a 5% level and ** indicates significant at a 10% level.

[a] Standard deviations are in parentheses.

[b] $\eta_{ij} = \frac{\gamma_{ij}}{w_i} - \beta_i \frac{w_j}{w_i} - \delta, \ \delta = 1 \text{ for } i = j, \delta = 0 \text{ for } i \neq j.$

Table 8.2. Compensated elasticities from Chapter 4[a,b]

	Fresh	Frozen	Smoked	Expenditure
Fresh	-1.223*	0.677*	0.546*	1.355*
	(0.2220)	(0.1698)	(0.2454)	(0.1331)
Frozen	0.626*	-0.232	-0.413*	0.158
	(0.1571)	(0.2347)	(0.1828)	(0.1449)
Smoked	0.879*	-0.717*	-0.161	1.891*
	(0.2454)	(0.3179)	(0.1823)	(0.1005)

* indicates significant at a 5% level and ** indicates significant at a 10% level.

[a] Standard deviations are in parentheses.

[b] $\eta^*_{ij} = \frac{\gamma_{ij}}{w_i} + w_j - \delta, \ \delta = 1 \text{ for } i = j, \delta = 0 \text{ for } i \neq j.$

Table 8.3. Uncompensated elasticities from Chapter 5[a,b]

	Fresh	Frozen	Smoked	Expenditure
Fresh	-1.584*	0.186	0.155	1.242*
	(0.165)	(0.305)	(0.159)	(0.287)
Frozen	0.441*	-0.756*	-0.146	0.462
	(0.179)	(0.364)	(0.139)	(0.320)
Smoked	0.115	-0.770*	-0.975*	1.629*
	(0.174)	(0.296)	(0.311)	(0.316)

*indicates significant at a 5% significance level and indicates significant at a 10% significance level.

[a] Standard deviations are in parentheses.

[b] The uncompensated elasticities are given as

$$\eta_{ij} = \frac{\gamma_{ij}}{w_i} - \beta_i \frac{w_j}{w_i} - \delta, \quad \delta = 1, \ i = j, \ \delta = 0, \ i \neq j.$$

Table 8.4. Compensated elasticities from Chapter 5[a,b]

	Fresh	Frozen	Smoked	Expenditure
Fresh	-1.137*	0.708*	0.429*	1.242*
	(0.200)	(0.236)	(0.138)	(0.287)
Frozen	0.607*	-0.562**	-0.048	0.462
	(0.202)	(0.288)	(0.132)	(0.320)
Smoked	0.702*	-0.085	-0.607*	1.629*
	(0.226)	(0.252)	(0.202)	(0.316)

*indicates significant at a 5% significance level and ** indicates significant at a 10% significance level.

[a] Standard deviations are in parentheses.

[b] The compensated elasticities are given as $\eta_{ij}^{*} = \frac{\gamma_{ij}}{w_i} + w_j - \delta, \quad \delta = 1, \ i = j, \ \delta = 0, \ i \neq j.$

The own-price elasticities for fresh salmon are always elastic. However, the magnitudes are rather low compared to many earlier studies, as the highest point estimate is -1.725. This is in accordance with a trend in studies of the demand for salmon in reporting own-price elasticities of lower magnitudes when more recent data sets are used, see also Figure 5.1.[3] The own-price elasticities for frozen salmon are always found to be inelastic, and in some cases not significantly different form zero. The own-price elasticities of smoked salmon are found to be inelastic, but the uncompensated elasticity in Chapter 5 is very close to unity.

For the expenditure elasticities, the two approaches in Chapters 4 and 5 agree in qualitative terms, but the magnitudes of the elasticities differ somewhat. The expenditure elasticity for fresh salmon is found to be elastic, but only barely so (1.35 and 1.42). Also for the expenditure elasticity there has been a trend in the literature of reporting less elastic elasticities when recent data sets are used.[4] The expenditure elasticity for frozen salmon is always found to be inelastic, while the expenditure elasticity for smoked salmon is always elastic, and significantly different from one.

The demand system analyses in Chapters 4 and 5 indicate that a dynamic specification is appropriate for the salmon market in the European Union. The results in Chapter 7, where a more detailed analysis of the adjustment process is undertaken, confirm this. The results indicate that there is a significant time lag from when a change in price or

[3] The trend in the own-price elasticities does not seem to depend on whether a single equation or a system specification is used. See e.g. Asche, Salvanes and Steen (1994) for a system specification that provides a strongly elastic own-price elasticity for fresh salmon. This is in contrast to what is the case with expenditure elasticities, where the studies using system specifications seem to report lower elasticities than the studies using single equation specifications.
[4] Note that the studies using system specifications always seem to report lower elasticities than the studies using single equation specifications.

expenditure takes place until it is fully reflected by the demanded quantity. This feature may have several explanations, including habit formation and informal relationships between exporters and importers.

8.4 Policy Implications

The estimated elasticities may be valuable when analysing several policy issues relating to the salmon market. The own-price elasticity for fresh salmon, which is the most important product form in the European salmon market, still seems to be elastic. However, if its magnitude continues to decline with the expansion of the market, it may soon be inelastic. The decreasing magnitude of the elasticity does indicate that it is getting harder to increase income from fresh salmon by increasing the supply, see also Figure 5.1. If the elasticity continues to decline, it may soon be impossible.

The demand for frozen salmon appears to be inelastic. This is reasonable, as most wild-caught Pacific salmon is available in this product form. Accordingly, the frozen salmon segment may be the part of the salmon market with the keenest competition. The own-price elasticity for smoked salmon also seems to be inelastic. Together with the current high tariff, this implies that this market segment cannot become very important for exporters to the European Union.[5] Hence, the market segment for fresh salmon seems to have the strongest growth potential. However, it seems difficult to increase the income from the salmon market much further by increasing the supply. Marketing and other factors that may cause shifts in the demand schedule are accordingly of importance if the growth in the salmon market is to continue.

---

[5] Imports of smoked salmon face a tariff of 13%, compared to 2% for fresh and frozen salmon.

The question as to whether some producers of farmed salmon have market power has been, and still is, an important issue in the European salmon market. Many people inside the industry seem to believe that Irish and Scottish farmers, together with Norwegian farmers, have market power if they are able to act as a unit. For this reason there have been negotiations with the objective of forming a European producer organisation, whose aim is to control supply, and thereby prices in the European salmon market.[6]

The probability of success for a producer organisation is critically dependent on the possible substitution relationships in the market. In particular in the market for fresh salmon it is possible that a producer organisation could have market power if there are no close substitutes for fresh salmon, as the producers who would compromise the producer organisation today supply more than 90% of the European Union's fresh salmon. There is some potential for competition in the fresh market, mainly from Chile, with a salmonid production of about 78,000 tonnes (Bjørndal, 1996), if the price margin becomes large enough to justify airfreight of Chilean salmon. However, if frozen salmon is a close substitute to fresh salmon, then the possibility to gain market power is small. This is because the available quantities of wild-caught Pacific salmon are larger than European demand. Further, transportation costs do not disfavour frozen Chilean salmon in the way they do for fresh. The farmers that would

[6] There are also other arguments in favour of a producer organisation based on the instability of the production process, see Bjørndal and Salvanes (1995).

make up the producer organisation are also supplying large quantities of frozen salmon.

When analysing the substitution relationship between two goods, the compensated cross-price elasticities are the appropriate choice, as they measure the pure substitution effect. This may be particularly important in markets such as the salmon market, where the rapid expansion of the market is important for the measurement of expenditure. As noted above, fresh salmon is a substitute for both frozen and smoked salmon, and an increase in the price of fresh salmon will increase the demand for frozen and smoked salmon. Hence, fresh salmon competes with both frozen and smoked salmon. This result is supported by Steen (1994), who in a market delineation study finds that the three product forms seem to compete in the same market. The potential to exploit market power in the fresh salmon market accordingly seems to be limited.

As a note to the discussion of market power in the salmon market, a particularly interesting episode took place in 1990-91. Norwegian farmers had a market share in Europe of more than 60%, and all the Norwegian farmers had a mandatory membership in a sales organisation. To stabilise and increase the price of fresh salmon, the most important product form for Norwegian farmers, a freezing program was implemented in 1990 by the sales organisation to limit the supply of fresh salmon. Over the period about 88,000 tons of salmon were frozen. However, the price continued to decline and the freezing program was abandoned in November 1991, when the sales organisation went bankrupt. One explanation for the failure of the Norwegian farmers' sales organisation's freezing program in 1990-91 may be that the possibility to substitute frozen salmon for fresh made it impossible to exploit the market power that a market share of over 60% should have indicated.

In Norway, there have also been discussions about the possibility of stabilising the price of fresh salmon by diversifying the product through processing and supplyimg different market segments. However, if it is possible to substitute fresh salmon with a processed form, as our results indicate is the case with frozen and smoked salmon, there seems to be limited scope for increased stability in the price of fresh salmon through processing.

8.5 Concluding Remarks

The empirical results in this dissertation may contribute to the knowledge of the structure in the salmon market, by considering more product forms than earlier studies. In particular, the demand for both frozen and smoked salmon, the relationship between these two product forms, and their relationship to fresh salmon has received little attention in earlier works. However, much work is still left before we can obtain a good understanding of the salmon market in the European Union.

The frozen product form contains both wild-caught Pacific salmon and farmed Atlantic salmon. It is not likely that these are perfect substitutes, and a disaggregation of the frozen salmon category may provide more knowledge. Recently, other product forms of salmon, in particular fresh and frozen fillets, as well as dinner ready packings, have become more common. It is not likely that these product forms are perfect substitutes for the more traditional product forms, and both their demand and their relationships to the established product forms are of interest. There may also be regional differences in demand that are not possible to capture when analysing data at the European Union level.

The origin of the farmed salmon may also be of importance. It is not clear to what extent farmed salmon from different countries may be regarded as perfect substitutes. However, there are indications that salmon from different sources are not regarded as perfect substitutes, and the generic marketing of a concept such as Norwegian

Superior Salmon clearly shows that some agents in the market try to connect origin and quality. In this context, it is also of interest to see how important the tariff of 2% for salmon imports into the European Union is for Irish and Scottish salmon farmers.

The results of earlier studies (see Chapter 3) and this dissertation indicate that there may not be a separate market for salmon in Europe, as prices are exogenous in the demand equations. Whether there exists a world market, or if one of the other markets, e.g. Japan, is price leading is still an open question. Hence, analyses of the relationships between the different markets and a model of world demand and supply would be useful for obtaining better knowledge about the price generating mechanism in the market.

REFERENCES

Anderson, G. J. and R. W. Blundell (1982) "Estimation and Hypothesis Testing in Dynamic Singular Equation Systems," *Econometrica,* 50, 1559-1571.

Anderson, G. J. and R. W. Blundell (1983) "Testing Restrictions in a Flexible Demand System: An Application to Consumers' Expenditure in Canada," *Review of Economic Studies,* 50, 397-410.

Anderson, G. J. and R. W. Blundell (1984) "Consumer Non-Durables in the U.K.: A Dynamic Demand System," *Economic Journal,* 94, 35-44.

Asche, F., K. G. Salvanes, and F. Steen (1994) "Market Delineation and Demand Structure." Centre for Research in Economics and Business Administration. Working Paper no. 106/94.

Bird, P. (1986) "Econometric Estimation of World Salmon Demand," *Marine Resource Economics,* 3, 169-182.

Bjørndal, T. (1996) "Genetic Improvement of Coho Salmon in Chile: An Economic Analysis," Mimeo. Norwegian School of Economics and Business Administration.

Bjørndal, T., D. V. Gordon, and K. G. Salvanes (1994) "Elasticity Estimates of Farmed Salmon Demand in Spain and Italy," *Empirical Economics,* 4, 419-428.

Bjørndal, T., D. V. Gordon, and B. Singh (1993) "A dominant Firm Model of Price Determination in the US Fresh Salmon Market: 1985-1988," *Applied Economics,* 25, 743-750.

Bjørndal, T. and K. G. Salvanes (1995) *Perspektiv på Fiskeoppdrett: Mellom Marknad og Regulering* (Perspectives on Aquaculture: Between Market and Regulation), Oslo: Det Norske Samlaget.

Bjørndal, T., K. G. Salvanes, and J. H. Andreassen (1992) "The Demand for Salmon in France: the Effects of Marketing and Structural Change," *Applied Economics,* 24, 1027-1034.

Chambers, M. J. (1993) "Consumers' Demand in the Long Run: Some Evidence from UK Data," *Applied Economics,* 25, 727-733.

Deaton, A. S. and J. Muellbauer (1980) "An Almost Ideal Demand System," *American Economic Review,* 70, 312-326.

DeVoretz, D. (1982) "An Econometric Demand Model for Canadian Salmon," *Canadian Journal of Agricultural Economics,* 30, 49-60.

DeVoretz, D. J. and K. G. Salvanes (1993) "Market Structure for Farmed Salmon," *American Journal of Agricultural Economics,* 75, 227-233.

Godfrey, L. G. (1981) "On the Invariance of the Lagrange Multiplier Test with Respect to to Certain Changes in the Alternative Hypothesis," *Econometrica,* 49, 1443-1455.

Hansen, B. E. (1992) "Efficient Estimation and Testing of Cointegration Vectors in the Presence of Deterministic Trends," *Journal of Econometrics,* 53, 87-121.

Hendry, D. F. (1995) *Dynamic Econometrics*, Oxford: Oxford University Press.

Herrmann, M., R. C. Mittelhammer, and B. H. Lin (1992) "Applying Almon-Type Polynomials in Modelling Seasonality of the Japanese Demand for Salmon," *Marine Resource Economics,* 7, 3-13.

Herrmann, M. L. and B. H. Lin (1988) "The Demand and Supply of Norwegian Atlantic Salmon in the United States and the European Community," *Canadian Journal of Agricultural Economics,* 38, 459-471.

Herrmann, M. L., R. C. Mittelhammer, and B. H. Lin (1993) "Import Demand for Norwegian Farmed Atlantic Salmon and Wild Pacific Salmon in North America, Japan and the EC," *Canadian Journal of Agricultural Economics,* 41, 111-125.

Kabir, M. and N. B. Ridler (1984) "The Demand for Atlantic Salmon in Canada," *Canadian Journal of Agricultural Economics,* 32, 560-568.

Phillips, P. C. B. and B. E. Hansen (1990) "Statistical Inference in Instrumental Variables Regressions with I(1) Processes," *Review of Economic Studies,* 57, 99-125.

Phillips, P. C. B. and M. Loretan (1991) "Estimating Long-Run Economic Equilibria," *Review of Economic Studies,* 58, 407-436.

Steen, F. *Testing for Market Boundaries and Oligopolistic Behavior: An Application to the European Market for Salmon.* Ph.D Dissertation, Norwegian School of Economics and Business Administration, 1994.

Veall, M. R. and K. F. Zimmermann (1986) "A Monthly, Dynamic Consumer Expenditure System for Germany with Different Types of Households," *Review of Economics and Statistics,* 68, 256-264.

Wessells, C. R. and J. E. Wilen (1993) "Economic Analysis of Japanese Household Demand for Salmon," *Journal of the World Aquaculture Society,* 24, 361-378.

Wessells, C. R. and J. E. Wilen (1994) "Seasonal Patterns and Regional Preferences in Japanese Household Demand for Seafood," *Canadian Journal of Agricultural Economics,* 42, 87-103.

Wickens, M. R. and T. S. Breusch (1988) "Dynamic Specification, the Long-Run and the Estimation of Transformed Regression Models," *Economic Journal*, 98, 189-205.