Marine Resource Economics, Volume 12, pp. 221–237
Printed in the U.S.A. All rights reserved.
0738-1360/97 $3.00 + .00

Dynamic Adjustment in Demand Equations

FRANK ASCHE
Norwegian School of Economics and Business Administration

Abstract *The focus of this paper is the dynamic adjustment of demand. It is shown that a dynamic specification of the demand equation provides information on: (i) the level of response to a price or expenditure change taking place instantaneously, (ii) how much the adjustment that has taken place after any number of periods, and (iii) how long it takes for the price change to be fully reflected in the demand. The importance of the dynamic adjustment is shown for the import demand for fresh and frozen salmon in the European Union. The results indicate that, for these product forms, only about 10% of the adjustment from a price or expenditure change takes place instantaneously, that over 60% of the adjustment has taken place after three months, but that it takes almost a year before the change is fully reflected in the demand.*

Key words Demand, dynamic adjustment, salmon.

Introduction

It has been recognized for a long time that dynamics may be important when considering demand equations. This is because the demand for a product may deviate from the 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, monetary or psychological, when demand deviates from equilibrium. This adjustment cost can be caused by different circumstances; for instance habit formation, imperfect information, or contractual obligations. 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 salmon market has been quite volatile the last decade, and a dynamic specification seems to be appropriate.[1] This is also indicated by several earlier studies on the demand for salmon. Different specifications of the dynamics have been used including habit formation models (Bjørndal, Salvanes, and Andreassen 1992; Bjørndal, Gordon and Salvanes 1994), models with autoregressive errors (Wessells and Wilen 1993, 1994; Asche 1996a), state space models (Vukina and Anderson 1994; Gu and Anderson 1995) and error correction models (Bird 1986; Asche 1996b; Asche, Salvanes, and Steen 1997). However, even though dynamic specifica-

Frank Asche is associate professor at the Centre for Fisheries Economics, Norwegian School of Economics and Business Administration, Helleveien 30, N-5035 Bergen-Sandviken, Norway; e-mail: Frank.Asche@snf.no.
I thank Trond Bjørndal, Kjell G. Salvanes, Cathy R. Wessells and two anonymous referees for valuable comments. Financial support from the Norwegian Research Council is also acknowledged.
[1] It must be noted that volatility in production does not need to affect the 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.

tion 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, information about the dynamic adjustment process is also important. This is particularly true for the salmon market since attempts to increase prices by regulating the market have been undertaken several times primarily in Europe but also in the United States. Examples include: (*i*) the Norwegian freezing program in 1990–91 where Norwegian farmers tried to raise the price of fresh salmon by holding supply and freezing large quantities of salmon; (*ii*) the U.S. countervailing duty on Norwegian fresh salmon imports implemented in 1991 after dumping charges; (*iii*) minimum import prices to the European Union for limited periods, most recently on 16 December 1995; and (*iv*) feeding quotas imposed on Norwegian farmers to restrict production in 1995–96.[2]

The effectiveness of regulations depends on the demand side of the response to changes. If the demand schedule is steep, relatively minor changes in the supplied quantity can affect price substantially. On the other hand, if demand is elastic, it is more difficult to affect price by regulating quantity. As noted above, several studies have indicated that dynamics are important in salmon demand. This implies that the demand schedule is steeper in the short than in the long-run. Hence, the opportunity to affect the market by regulations seems to be greater in the short-run than in the long-run. It must be noted that whether regulations will work also depends on the regulators ability to control supply.

This paper focuses on the dynamic adjustment of the import demand for the two most important product forms of salmon in the European Union: fresh and frozen. This will provide 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. While the speed of adjustment has received some attention in the literature on factor demand, and in macroeconomic work, it has received less attention when consumer and import demands are considered.[3] An exception is the case where the habit formation model is used, particularly when estimating import demand (Goldstein and Khan 1985). In these studies, a measure of how much adjustment takes place instantaneously is provided.

In this paper, 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 about many aspects of the adjustment process following, for example, a price change. This includes how much the adjustment takes place instantly, as well as information about how much 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. This includes the almost ideal demand system (AIDS). This follows from the singularity problems caused by the expenditure share specification (Anderson and Blundell 1983).[4] However, with a single equation demand specification, these pa-

---

[2] Several of these measures are further commented upon in Asche (1997).

[3] 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).

[4] This is also in contrast to the situation for factor demand specifications, where functional forms such as the generalized Leontief and the normalized quadratic allow the adjustment parameters to be identified (Asche and Salvanes 1996).

rameters can be identified. Hence, while demand system analysis is suitable when one wants to conduct analysis based on consumer theory, and when obtaining elasticity estimates is the main objective, issues such as dynamic adjustment need other specifications.

This paper is organized as follows. The data set is presented in the next section with a brief discussion of the salmon market following. Economic arguments suggesting why demand can deviate from the long-run equilibrium for periods of time follows. In the fourth section, the error correction model used to specify the demand equations is discussed with attention focused on the information that is provided about the adjustment parameters. Then issues concerning the time-series properties of the data are discussed before the empirical results are reported. Last, some concluding remarks are given.

Data and the Salmon Market

The data set used in this paper consists of import data from the European Union's trade statistics, Eurostat. The set contains data series with 144 observations on the value (in ECU) and quantity (tons) of monthly imports into the European Union of fresh and frozen salmon for the period January 1981 through December 1992.[5] The price on smoked salmon imports are also included as a substitute price in the demand functions. This price is constructed from import values and quantities from the same source as the other data. 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 instead. This measure is comparable to the expenditure measure used in Asche (1996a; 1996b), and should be a good measure if the weak separability condition invoked there holds.[7] Real values were obtained using OECD's consumer price index for the European Union.

The introduction of farmed salmon has greatly transformed the salmon market, particularly in Europe, and the quantities in demand have increased vastly. Imports of salmon by the European Union were 35,000 tons in 1981, and increased to

[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 also likely to be small.

[6] Aggregate income measures, such as gross national product or private final consumption, usually have little variation and strongly resemble a linear trend with few kinks.

[7] There are two lines of reasoning that make the weak separability assumption plausible. First, market delineation studies indicate that the assumption may not be too restrictive since salmon is not in the same market segment as many other seafood products. In particular, Gordon, Salvanes, and Atkins (1993) conclude that salmon does not compete in the same market segments as turbot and cod in the European markets. As this also implies that salmon does not compete in the same market segments 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 other types of fish. There may still be a potential problem with other high-valued sea food products. However, as their budget shares are mostly very low, the impact of omitting them should not be too large, if they indeed do belong to the same market segment as salmon. Second, in most studies of salmon demand, either other kinds of seafood are not considered in the analysis, or a single category of salmon is analyzed together with other seafood products. In the first case, other seafood products are omitted when analyzing demand for different species of salmon, presumably because they are not thought too important. In these studies, salmon is not divided into different product categories, which implies that different product forms of salmon are considered first at a lower branch in the utility tree. Wessells and Wilen (1993, 1994) are exceptions to this practice.

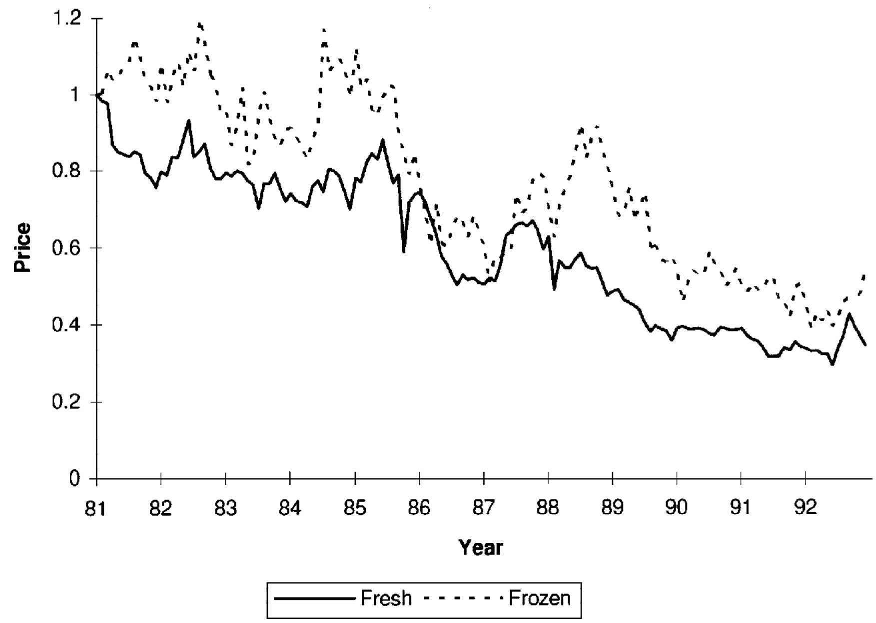

Figure 1. Normalized Prices for Salmon Imports (January 1981=1)

177,000 tons in 1992. The preferred product forms have also changed. In 1981, 29,500 tons of frozen salmon were imported, mostly wild caught Pacific salmon 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 approximately 50% was from North America. The real prices and quantities of fresh and frozen salmon imported by the European Union are graphed in figures 1 and 2. To enable a comparison of the volatility and the strength of trends in the data series, they are normalized to one in January 1981. For both product forms there is an upward trend in imported quantities, and this trend is particularly strong for fresh salmon. The prices have a downward trend.

The imported quantities of salmon exhibit strong seasonality. This can be seen in figure 2, and is evident in figure 3, where average monthly consumption of the two product forms is shown for the period 1981–92. There is a strong seasonal peak in late fall, and a weak one in spring. This is due primarily to traditional holiday consumption of salmon, particularly before Christmas. Note also that imports of frozen salmon peaks earlier than fresh 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.

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.

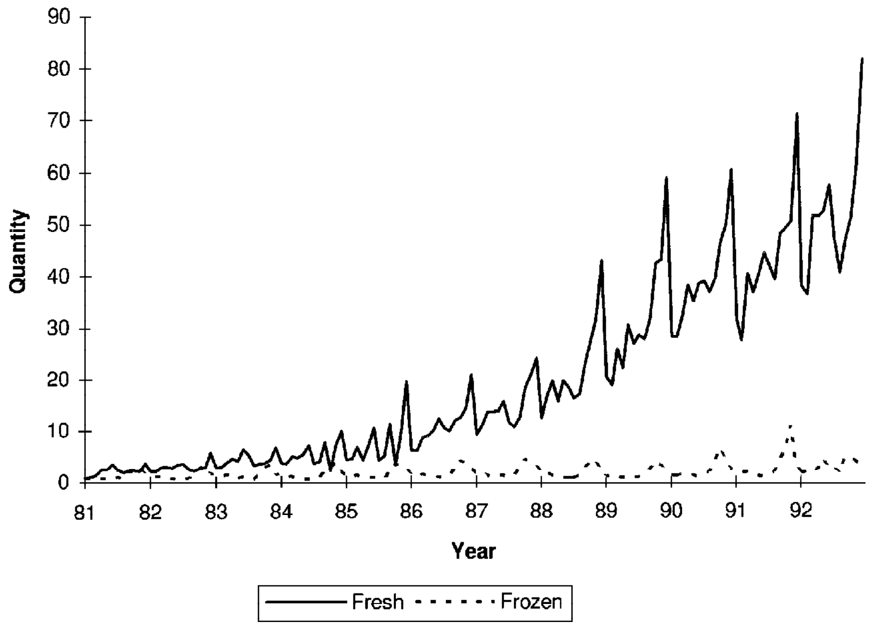

Figure 2. Normalized Quantities for Salmon Imports (January 1981=1)

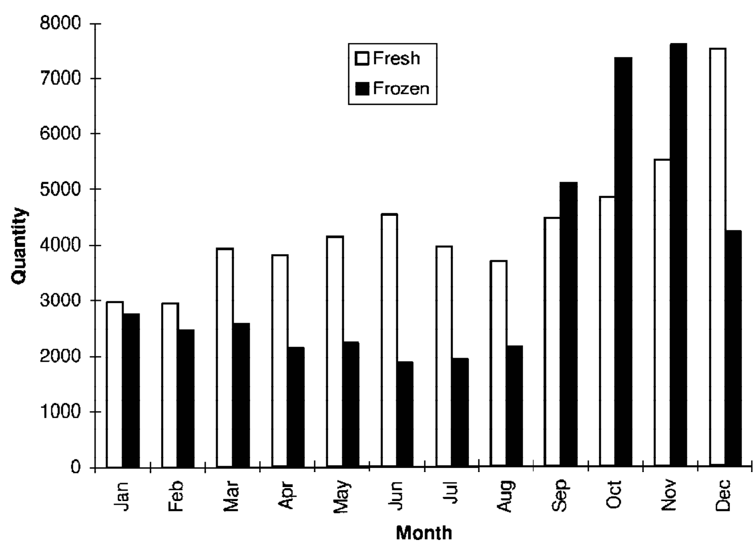

Figure 3. Monthly Averages of Salmon Imports 1981–92

Why Does Demand Deviate from Long-Run Equilibrium?

There are many explanations 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 can 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 (*e.g.*, changes in prices or income). This representation can be reasonable with addictive products, for products that you may have real affinity, 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 suggests that factors like contractual obligations and imperfect information can cause demand to deviate from equilibrium. Recently, these reasons for deviations from a long-run equilibrium have gained much attention, particularly in the field of industrial organization. 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 decision 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 been fully 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. Hence, marketing costs may affect the dynamic adjustment. There also seem to be more or less formal bindings between some exporters and importers (Lines 1995). If these bindings are formal, they will directly limit 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 growth in the supply of salmon, new markets have been found. Knowledge about salmon has been determined to play an important role in the demand of these markets, indicating that a habit formation effect may be important (Bjørndal, Salvanes, and Andreassen 1992).

Dynamic Specification

Consumer theory indicates that the demand 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).[8] This can be written as

$$q_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i q_{t-i} + \sum_{m=1}^{n} \sum_{j=0}^{q} \beta_{mj} p_{m,t-j} + \sum_{k=0}^{r} \gamma_k x_{t-k} + e_t \qquad (1)$$

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 equation (1) is found by setting all the variables equal at every time t, *i.e.*,

$$q = \frac{a_0}{1 - \sum_{i=1}^{p} a_i} + \frac{\sum_{m=1}^{n} \sum_{j=0}^{q} b_{mj}}{1 - \sum_{i=1}^{p} a_i} p_m + \frac{\sum_{k=0}^{r} g_k}{1 - \sum_{i=1}^{p} a_i} x + e_t = a_0 + \sum_{m=1}^{n} b_m p_m + gx + e_t. \qquad (2)$$

A representation of equation (1) that has been popular for the last decade is the error correction model. This is a restriction free transformation of equation (1), and can be written as

$$\Delta q_t = \sum_{i=1}^{p-1} a_i \Delta q_{t-i} + \sum_{m=1}^{n} \sum_{j=0}^{q-1} b_{mj} \Delta p_{m,t-j} + \sum_{k=0}^{r-1} g_k \Delta x_{t-k} \qquad (3)$$
$$- a_P \left(q_{t-P} - a_0 - \sum_{m=1}^{n} b_m p_{m,t-Q} - g x_{t-R} \right) + e_t$$

where

$$a_i = \sum_{i=1}^{i} \alpha_i - 1, \quad b_{mj} = \sum_{j=0}^{j} \beta_{mj}, \quad g_k = \sum_{k=0}^{k} \gamma_k.$$

The main advantage with equation (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 an effect (*i.e.*, is different from zero) only when the de-

---

[8] 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).

mand 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.[9] 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.[10] When the 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 the adjustment takes place in later periods (the effect of the lagged quantities, $\Sigma_i\alpha_i$, yields the adjustment in later periods). 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.[11] 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.[12] 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 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.

---

[9] 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.

[10] 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.

[11] The term dynamic multiplier is used in the univariate time-series literature (see Hamilton 1994, p. 3).

[12] Note also that to find the total effect of any of the exogenous variables at any lag, the parameter on the variable in question must be divided by the corresponding dynamic multiplier.

Table 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
Income	0.167	11

Critical value is –2.881 at a 5% level and –2.577 at a 10% level (MacKinnon 1991).

Integration and Cointegration

It is now widely recognized that most economic data series tend to be nonstationary, and figures 1 and 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), where the number of lags are chosen so that the residuals in the test show no evidence of autocorrelation. The results are reported in table 1, and all the data series seem to be nonstationary.[13] Note that while one lag seems sufficient for the prices, eleven are used with the quantities. This corresponds well to the strong seasonality in the quantity series, but the weak or absent seasonality in prices.

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 (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 2, and the data series in all demand equations seem to be cointegrated.

Empirical Results

To estimate the demand equations for fresh and frozen 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.[14] The advantage with the two-step estimator

[13] All estimation and tests in this chapter were done with the econometric software package Shazam (White 1978).
[14] 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.

Table 2
Long-Run Parameter Estimates (Elasticities)

	Equation	
Variable	Fresh	Frozen
Fresh price	–0.594	0.495
Frozen price	0.070	–1.179
Smoked price	0.111	–0.508
Income	0.372	1.326
Trend	0.019	–0.012
Constant	3.028	–2.184
R^2	0.949	0.813
Cointegration test	–9.624	–9.392

Critical value for the cointegration tests is –4.531 at a 5% level and –4.225 at a 10% level (MacKinnon 1991).

is that even though equation (3) is nonlinear, all the parameters can be estimated with 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.*,

$$q_t = a_0 + \sum_{i=F,Z,S} a_i p_{i,t} + g x_t + e_t \tag{4}$$

where F indicates fresh, Z is frozen, and S is smoked salmon.[15] Engle and Granger show that these estimates are super consistent, but normal inference theory does not apply. In the demand equations, the price of smoked salmon is also included as a substitute price. This is because a large part of the fresh and frozen salmon imported are purchased by the smoking industry and substantial quantities of smoked salmon are also imported. Hence, imports of fresh and frozen salmon that are used by the smoking industry may depend on the price of smoked salmon imports. A demand equation for smoked salmon will not be estimated here, since it would be difficult to interpret because of the large smoking industry inside the EU.

The results from estimating the long-run relationship given in equation (4) are reported in table 2. The signs on the elasticities are all similar to earlier studies.[16] However, the own-price and income effects for fresh salmon are somewhat weaker than what is normally reported. It should be noted that in studies using recent data sets, there seem to be a declining trend for the magnitude of the own-price effects for fresh salmon. The own-price response is rather strong for frozen salmon, indicating that it is the increased imports of frozen Atlantic salmon that might be the most important factor.[17] Both frozen and smoked salmon are found to be substitutes to

[15] The prices are treated as exogenous. This is reasonable *a priori* since there seems to be a world market for salmon. This is also in line with the results from Hausman tests in DeVoretz and Salvanes (1993), Asche (1996b), and Asche, Salvanes, and Steen (1997), however, no formal tests are provided here.
[16] 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; and Bjørndal, Gordon, and Salvanes 1994). Recently the demand for different product forms of salmon have been estimated in demand systems (see Wessells and Wilen 1993, 1994; Asche 1996a,b; and Asche, Salvanes, and Steen 1997).
[17] The variable frozen salmon consist of both Atlantic and Pacific salmon. Over the period studied, imports of frozen Atlantic salmon have increased substantially, while imports of frozen Pacific salmon have remained relatively constant.

fresh, while smoked salmon seems to be a complement to frozen. While this result is a little surprising, it is reasonable given the fact that frozen salmon is mostly used as an input factor in the European smoking industry. It is also in accordance with the results in Asche (1996a,b), where different functional forms are used. 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 such as equation (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 sufficiently large number of lags must be chosen. We first tried with a model that covered one year, *i.e.*, eleven lags are specified. The estimated equation can then be written as

$$\Delta q_t = \sum_{i=1}^{10} a_i \Delta q_{t-i} + \sum_{m=F,Z,S} \sum_{j=0}^{10} b_{mj} \Delta p_{m,t-j} + \sum_{k=0}^{10} g_k \Delta x_{t-k} + \sum_{i=2}^{12} D_i d_i - a_P (ECM_{t-11}) + e_t \quad (5)$$

where *ECM* is the estimated long-run relationship from equation (4). The parameters from these regressions are reported in tables 3 and 4. 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 does not attempt to simplify the dynamic structures. Also note the seasonal peaks in late spring and before Christmas for fresh salmon.[18] The peaks for frozen salmon are somewhat earlier. This is reasonable because frozen salmon is most often used as an input factor by the European smoking industry. This corresponds well to the pattern shown in figure 3.

Note also that the short-run own-price effects are of substantially lower magnitudes than the long-run elasticities for both product forms. The short-run elasticity for fresh salmon is –0.039, while for frozen it is –0.639. That the magnitudes for the elasticities are lower in the short-run than in the long-run is predicted by the LeChatelier principle, and it also illustrates the importance of dynamics, since the short-run adjustment is substantially less than the long-run. However, the magnitudes of the short-run elasticities are extremely low, as they imply virtually no response to price changes in the short-run.

To facilitate the discussion of the dynamics, the adjustment parameters and dynamic multipliers are shown in table 5, and the cumulative adjustment, *i.e.*, the share of the adjustment that has taken place after *n* periods, is shown in table 6. The cumulative adjustment is also graphed in figure 4. The adjustment speed for both product forms is very slow as fresh salmon has an adjustment parameter of 0.121, while frozen is 0.106. This corresponds well to the low magnitude of the short-run elasticities, as one would expect slow dynamic adjustment to cause low magnitude on the elasticities. Even though the instantaneous adjustment is slow, most of the adjustment takes place over the next three months. For both 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.

The steep short-run demand schedules, and the slow adjustment, implies that it should be fairly easy to influence prices on both fresh and frozen salmon in the EU with relatively minor measures. However, for all regulatory measures undertaken in the salmon markets, the effect is doubtful. After the announcement of the Norwegian

---

[18] The seasonal dummies measure the deviations from January.

Table 3
Short-Run Estimates for Fresh Salmon

Variable	Estimate	St. Error	Variable	Estimate	St. Error
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.

freezing program, there was some evidence of a small price increase shortly after the program started, but this was short lived and disappeared long before the program was abandoned. The same seems to be true for most of the other measures in Europe, after a small initial price increase, the effect disappears. We have not estimated U.S. demand, but even if the short-run demand schedules were as steep as in Europe, it would be hard to find any effect on price of the U.S. duty on Norwegian salmon.[19]

The explanation for these failures to influence prices is probably grounded in

[19] There is, however, a clear effect on who supplies the market, as Canadian and Chilean salmon take over from Norwegian (see Anderson 1992).

Table 4
Short-Run Estimates for Frozen Salmon

Variable	Estimate	St. Error	Variable	Estimate	St. Error
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.

the fact that one must have market power to influence prices. Even if demand conditions are favorable to influence prices by restricting supply particularly in the short-run due to steep demand schedules, this is not sufficient if one does not control supply. A common feature in Europe and in the U.S. is that regulations do not affect all suppliers. None of the measures in Europe affect Irish and Scottish supply, and some of the measures only affect Norwegian supply. The U.S. duty affects only Norwegian supply. This might not be too bad, particularly in Europe, where an important part of the motivation for regulations are to support Irish and Scottish farmers. However, with steep short-run demand schedules, it takes only minor increases in supply from the producers not affected by the regulations, to offset the reduction in supply aimed at by the regulations. The effect of the regulations are therefore easily offset by the unregulated suppliers.

Table 5
Adjustment Parameters

	Equation	
Parameter	Fresh Salmon	Frozen Salmon
a_P	0.121	0.106
α_1	0.187	0.429
α_2	0.094	0.105
α_3	0.307	0.024
α_4	–0.050	0.108
α_5	0.044	–0.123
α_6	0.003	0.053
α_7	–0.087	0.145
α_8	–0.050	0.043
α_9	0.181	–0.028
α_{10}	0.091	0.070
α_{11}	0.163	0.067

Table 6
Cumulative Adjustment

	Equation	
Period	Fresh Salmon	Frozen Salmon
0	0.117	0.107
1	0.304	0.536
2	0.398	0.641
3	0.705	0.665
4	0.655	0.773
5	0.699	0.650
6	0.702	0.703
7	0.615	0.848
8	0.565	0.891
9	0.746	0.863
10	0.837	0.933
11	1.000	1.000

Concluding Remarks

In this paper, 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 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 product forms of salmon considered here. Only about 10% of the adjustment of a disequilibrium movement takes place instantaneously. The magnitude on the short-run price elasticities is also very low. However, more than 60% of the adjustment

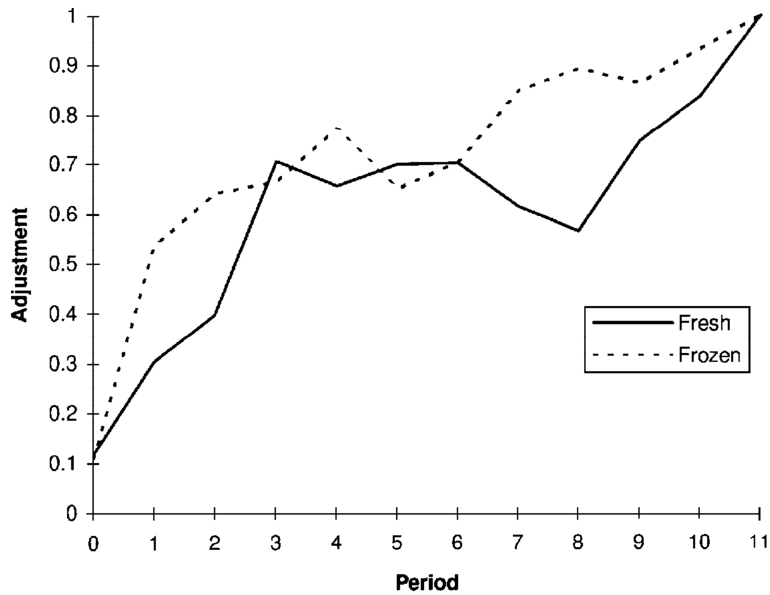

Figure 4. Cumulative Adjustment

takes place after three periods for all the product forms. Still, it takes an entire year before the change is fully reflected in demand. That there is a significant adjustment time before demand fully reflects changes in prices and other factors, implies that there are substantial adjustment costs for the purchasers of salmon. This is also reflected in the small magnitudes of the short-run own-price elasticities. The short-run demand schedules are therefore very steep, and the conditions for influencing the market by regulations in the short-run is quite favorable. However, for regulations to increase prices, it is of course also required that the regulator be able to control supply. This does not seem to be the case when regulations have been implemented in the salmon market, as none of the regulatory schemes mentioned in the introduction seem to have succeeded in raising prices.

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(July):397–410.

Anderson, J.L. 1992. Salmon Market Dynamics. *Marine Resource Economics* 7(Spring):87–88.

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

___. 1996b. *Specification of Dynamic Demand Systems: The Demand for Salmon in the European Union*. PhD Dissertation. Norwegian School of Economics and Business Administration.

___. 1997. Trade Disputes and Productivity Gains: The Curse of Farmed Salmon Production? *Marine Resource Economics* 12(Spring):67–73.

Asche, F., and K.G. Salvanes. 1996. Dynamic Factor Demand Systems and the Adjustment Speed Towards Equilibrium. *Canadian Journal of Economics* 29(special issue):S576–S581.

Asche, F., K.G. Salvanes, and F. Steen. 1997. Market Delineation and Demand Structure. *American Journal of Agricultural Economics* 79(February):139–50.

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 Assessment and Comparison. *Modeling and Measuring Natural Resource Substitution*, E.R. Berndt and B.C. Field, eds. pp. 259–289. Cambridge MA: MIT Press.

Bird, P. 1986. Econometric Estimation of World Salmon Demand. *Marine Resource Economics* 3(Summer):169–82.

Bjørndal, T., D.V. Gordon, and K.G. Salvanes. 1994. Elasticity Estimates of Farmed Salmon Demand in Spain and Italy. *Empirical Economics* 4(3):419–28.

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(December):1027–34.

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(December):661–92.

DeVoretz, D.J., and K.G. Salvanes. 1993. Market Structure for Farmed Salmon. *American Journal of Agricultural Economics* 75(February):227–33.

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(June):427–31.

___. 1981. Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root. Econometrica 49(July):1057–72.

Engle, R.F., and C.W.J. Granger 1987. Co-integration and Error Correction: Representation, Estimation and Testing. *Econometrica* 55(March):251–76.

Ezekiel, M. 1938. The Cobweb Theorem. *Quarterly Journal of Economics* 52(February):255–80.

Goldstein, M., and M.S. Khan. 1985. Income and Price Effects in Foreign Trade. *Handbook of International Economics.* R.W. Jones and P.B. Kenen, eds. pp. 1041–1105. New York: Elsevier.

Gu, G., and J.L. Anderson 1995. Deseasonalized State-Space Time Series Forecasting with Applications to the U.S. Salmon Market. *Marine Resource Economics* 10(Summer):171–85.

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(Spring):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(November):459–71.

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(March):111–25.

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

Lines, R. 1995. *Strategier for Konkurransedyktige Eksportbedrifter: Vurderinger Basert på Kjøpsatferd i tre Europeiske Markeder* (Strategies for Competitive Export Firms: Analysis of Market Behavior in three European Markets), SNF-Report 15/95.

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(1):64–74.

MacKinnon, J.G. 1991. Critical Values for Co-Integration Tests. in *Long-Run Economic Relationships.* R.F. Engle and C.W.J. Granger, eds. pp. 267–76. Oxford: Oxford University Press.

Nadiri, M.I., and S. Rosen. 1969. Interrelated Factor Demand Functions. *American Economic Review* 59(3):457–71.

Nickell, S.J. 1986. "Dynamic Models of Labour Demand." in *Handbook of Labor Economics*, O. Ashenfelter and R. Layard, eds. pp. 473–522. Amsterdam: North-Holland.

Phillips, P.C.B. 1986. Understanding Spurious Regressions in Econometrics. *Journal of Econometrics* 33(2):311–40.

Pindyck, R.S., and J.J. Rotemberg. 1983. Dynamic Factor Demand and the Effects of Energy Price Shocks. *American Economic Review* 73(5):1066–79.

Pollak, R.A. 1970. Habit Formation and Dynamic Demand Functions. *Journal of Political Economy* 78(4): 745–63.

Vaage, K. 1992. The Dynamics of Residential Electricity Demand: Empirical Evidence from Norway. SNF Working Paper No. 134/1992.

Vukina, T., and J.L. Anderson. 1994. Price Forecasting with State-Space Models of Nonstationary Time Series: The Case of the Japanese Salmon Market. *Computers and Mathematics with Applications* 27(1):45–62.

Wessells, C.R., and J.E. Wilen. 1993a. Economic Analysis of Japanese Household Demand for Salmon. *Journal of the World Aquaculture Society* 24(3):361–78.

___. 1993b. Inventory Dissipation in the Japanese Wholesale Salmon Market. *Marine Resource Economics* 8(Spring):1–16.

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