An Economic Analysis of Atlantic Salmon Markets

Biing-Hwan Lin and Mark Herrmann

A. E. Research Series No. 260

Presented at

Symposium on Markets for Seafood and Aquacultural Products
Charleston, South Carolina
August 19-21, 1987

Sponsored by

The International Institute of Fisheries Economics and Trade
and
The South Carolina Wildlife and Marine Resources Department

This work is a result of research supported by the Alaska Sea Grant College Program, cooperatively supported by the U.S. Department of Commerce, NOAA Office of Sea Grant and Extra-Mural Programs, under the Grant number NA86AA-D-SG041, project number R/14-09. Ron Rogness compiled most of the data used in this research. Norwegian data provided by Johan Muri of the Norwegian Export Committee for Fresh Fish is appreciated.

Biing-Hwan Lin is an assistant professor, Department of Agricultural Economics, University of Idaho. Mark Herrmann is a Ph.D. candidate and USDA Marketing Fellow, Department of Agricultural Economics, Washington State University.

Introduction

Recent success in the production of cultured Atlantic salmon in Norway has stimulated worldwide interest in salmon farming. Many Norwegian salmon farming companies have expanded their operations abroad as they face government regulations on size of operation and license requirements at home. Consequently, Norway is exporting both fish and farming technology at the same time by setting up joint venture endeavors abroad. This proliferation in farming salmon will certainly increase the world supply of cultured salmon rapidly.

Norway produced 27,200 metric tons (mt) of Atlantic salmon in 1985 and plans to increase production to 80,000 mt by 1990. As the supply increases, the price will decline if other things remain the same. Even though the demand for fish in the U.S., the leading consumer of cultured salmon, has been on the increase, it is likely that the rate of increase in supply will eventually outrun the increase in demand and hence force prices to drop. Due to this concern, the Norwegian government has encouraged fish farms to begin working with alternative species such as arctic char, Icelandic scallop, halibut, etc. (Riley 1986). It is obvious that the future demand for and price of Atlantic salmon is much needed information for those who have already invested or those who contemplate investing in salmon farming ventures.

Since 1984 the U.S. has replaced France as the leading importer of Norwegian cultured Atlantic salmon. In 1985 the U.S. bought 26% of Norwegian exports of fresh and frozen Atlantic salmon which amounted to more than 53 million pounds. It is expected that the U.S. imports of Norwegian Atlantic salmon will continue increasing as Norwegian production rises. Further, production of cultured salmon elsewhere is also targeted on the U.S. as a major market. This rapid increase in the importation of cultured salmon into the U.S. has raised great concerns within the U.S. Pacific salmon industry.

Fishermen of Pacific salmon are concerned about the impacts on the price for their catch of increased imports of cultured Atlantic salmon. This concern is acute because salmon fishing in many areas is an expensive endeavor due to the high value of fishing permits. The right to fish is usually transferable, and its market value is determined by the expected stream of future earnings from fishing. Therefore, the impact of Atlantic salmon imports on the exvessel price of Pacific salmon is a major parameter to be considered in fishermen's exit/entry decision in salmon fishing.

Because of the uncertainty associated with the effect of cultured salmon production on the price of the wild Pacific salmon catch, Alaskan salmon fishermen in general have been opposed to permitting salmon farming in Alaska. On the other hand, aquaculture advocates argue that the imports of cultured salmon provide high quality products all year round and hence expand the market for fresh/frozen Pacific salmon. In other words, as fresh salmon become available outside the Pacific salmon season, the number of consumers and their purchase frequency of Pacific salmon during the season increase. This increase in demand for Pacific salmon, suggest aquaculturists, is large enough to compensate for the competition created by imports of cultured salmon. The above argument should not be confused with the economic concept of complements. When two goods are complements, such as eggs and bacon, they are usually consumed at the same time. It is difficult to imagine these species of salmon are consumed together.

It is apparently widely believed that cultured Atlantic salmon is a substitute for certain species of Pacific salmon. However, salmon aquaculturists argue that imports and domestic production of cultured salmon have a positive overall impact on the market of Pacific salmon. To date, there is no hard evidence being generated to substantiate or quantify these beliefs and arguments.

Processors, wholesalers, retailers, and exporters/importers of salmon products will also certainly be affected by the influx of Atlantic salmon imports. The processing allocation of salmon landings among different production forms (i.e., canned vs. non-canned) was found to be affected by the prices of canned and non-canned salmon (Lin 1984). If the imports of Atlantic salmon affect the price of fresh and frozen Pacific salmon, the demand for canning and freezing services will change accordingly.

France is the second leading importer of both Norwegian cultured Atlantic salmon and U.S. Pacific salmon, so the increase in the exports of cultured salmon by Norway may impact both the U.S. export demand as well as the domestic demand for salmon. However, because of possible different end uses and different product forms involved, the relationship between cultured Atlantic and wild Pacific salmon in the domestic market may differ from that in the export market. Therefore, marketers of Pacific salmon at the wholesale level need to monitor the changes both in export and in domestic demand for their products in planning future marketing strategies.

While the imports of cultured Atlantic salmon may affect those involved in harvesting, processing, and marketing Pacific salmon, state agencies responsible for fishing regulations and salmon stock enhancement also need to understand and monitor this new market development. The harvest guidelines and length of commercial fishing season of Pacific salmon should be altered if the price of Pacific salmon is affected by imports of Atlantic salmon. Allocation of salmon stock between commercial and sport fishermen should also be revised for the same reason. Operation of public and private salmon hatcheries also need to consider the possible changes in their benefits or revenues induced by the imports of cultured Atlantic salmon. So clearly the imports of cultured Atlantic salmon have created legitimate concerns among those involved in the entire salmon fishing industry.

A market analysis is needed in order to provide answers to some of the concerns of the U.S. Pacific salmon fishing industry. This market analysis should address, at least, three issues. First, what is the current and future marketing relationship between cultured Atlantic and wild Pacific salmon? Are they substitutes? Since there are five species of Pacific salmon, we need to know what species are affected. Second, if cultured salmon is a substitute for its wild counterpart, what is the intensity of competition between them? Is the degree of competition stable or changing over time as imports of cultured salmon increase? Third, what will happen to the future demand for and the price of wild salmon when economic and political environments change? Since salmon is traded internationally, changes in exchange rates, trade barriers, transportation costs, and fishing and farming regulations will affect the market for both Pacific and Atlantic salmon.

The paper is organized as follows: the next section provides a brief review of the relevant literature; then the econometric models are discussed and empirical results presented, and following that is a discussion of future research needs.

Relevant Literature

The demand for canned Pacific salmon has been analyzed extensively in the past, but only a handful of studies have been conducted to analyze the demand for fresh and frozen Pacific and Atlantic salmon. Since this study focuses on the market for fresh/frozen Atlantic salmon, only the studies of fresh/frozen salmon are reviewed here.

DeVoretz (1982) estimated the Canadian demand for canned and fresh/frozen salmon using both the ordinary least squares and two-stage least squares methods. While the price dependent model produces satisfactory results for the market of canned products, the results of the fresh/frozen sector are disappointing. Lin (1984) estimated the domestic and export demand for Canadian canned salmon and North American (U.S. and Canada combined) canned and fresh/frozen salmon using the three-stage least squares method. Again, the Canadian markets for canned salmon were estimated with plausible and interesting results. But the results of the demand for fresh/frozen salmon produced in the U.S. and Canada were disappointing once again. Because there is no published data on the production of fresh/frozen salmon in the U.S., data problems were suspected to be one of the main reasons for the poor results.

Kabir and Ridler (1984) conducted the first study on the Canadian demand for wild Atlantic salmon using the single equation price dependent model. Their results suggest that the Canadian demand for fresh/frozen wild Atlantic salmon is a luxury good with an income elasticity around 4.0 and is price elastic with an elasticity in the neighborhood of 10. However, they failed to identify a substitute good (or goods) for Atlantic salmon. Lin (1986) re-estimated the Canadian demand for fresh/frozen wild Atlantic salmon using the Box-Cox flexible functional form and the price dependent model in which lobster was hypothesized as a substitute for Atlantic salmon. Results showed that the flexible functional form performed better than the log-linear functional form which also produced unstable estimates. The own-price, income, and cross-price elasticities were found to be 12.5, 8.3, and 4.2, respectively. Because Canada exported, on average between 1955 and 1982, more than 35% of its production of fresh/frozen Atlantic salmon, the simultaneous equation model should be estimated to check if the single equation model produces biased estimates.

Further, caution should be exercised in making inferences about the market potential for cultured salmon based upon the demand for wild salmon.

Riley (1986) estimated the U.S. demand for Norwegian fresh/frozen Atlantic salmon by regions (Northeast, West, and the rest of country). A single equation model was specified under the argument that the price variable is determined by the expected supply and cost which are approximated by previous rather than current supply and cost. Riley's model was constructed with sound economic reasoning and estimated by monthly data for the period from 1982 through 1984. However, results were rather weak as they failed to produce significant prices and income coefficients. Therefore, additional analyses of the demand for Atlantic salmon are still warranted in order to provide useful information to assist the U.S. salmon industry.

Models and Empirical Results

In this paper we report the preliminary results of three single equation models addressing the demand for and the supply of Norwegian Atlantic salmon. These three models were estimated to study (1) the U.S. demand for Norwegian Atlantic salmon and the relationship between cultured Atlantic and wild Pacific salmon; (2) the Norwegian supply of cultured Atlantic salmon to the U.S.; and (3) whether Atlantic and chinook salmon are substitutes in the French market. Each model and data set are discussed first and are followed by the summary of empirical results.

The U.S. demand for Norwegian Atlantic salmon

A 1985 study by the Aquaculture Project Group of the National Marine Fisheries Service (NMFS) states that chinook salmon is a strong competitor of Norwegian Atlantic salmon in the U.S. Further, in 1986 Rogness and Lin reported that U.S. seafood wholesalers in general consider fresh Atlantic salmon from Norway to be a substitute for fresh Pacific salmon. These assertions are tested in the estimation of the demand for Atlantic salmon.

The specification of the U.S. demand for cultured Atlantic salmon follows the economic theory in that the quantity consumed is hypothesized to be affected by its own-price, prices of substitutes, and income. Because the model was estimated by using monthly data, additional independent variables were added. The previous consumption was included to reflect the partial adjustment process of consumption behavior. In addition, a dummy variable for the period from June to October was created to capture the seasonal variation in the demand for Norwegian Atlantic salmon. Therefore, the demand function was specified as follows:

$$AQ_t = f(\ AP_t,\ KP_t,\ Y_t,\ AQ_{t-1},\ SEASON) \qquad (1)$$

where AQ is the per capita consumption (import) of Norwegian Atlantic salmon; AP is the real price of Atlantic salmon; KP is the real exvessel price of chinook salmon; Y is real per capita income; SEASON is the seasonal dummy variable (equal to 1 for those months from June through October and 0 otherwise); and subscripts t and t-1 denote the current and previous time periods, respectively.

When the price of cultured Atlantic salmon increases, consumers will consume less cultured Atlantic salmon and more of its substitutes. Therefore, AP is expected to have a negative effect on AQ. If chinook is a substitute for cultured Atlantic salmon, chinook price (KP) will have a positive effect on the consumption of Atlantic salmon (AQ). If Atlantic salmon is a normal and possibly a luxury good, income (Y) should have a positive effect on AQ, and the income elasticity will be greater than 1 for a luxury good. During the main fishing season of Pacific salmon, the availability of fresh Pacific salmon is expected to dampen the demand for cultured Atlantic salmon. Therefore, the seasonal dummy variable (SEASON) should have a negative effect on AQ. The lagged consumption of cultured Atlantic salmon (AQ_{t-1}) should have a coefficient falling between 0 and 1. The bigger the coefficient of AQ_{t-1}, the larger the effect of AQ_{t-1} on AQ_t, and hence, the longer the partial adjustment process.

A discussion of data is in order. The monthly import of data on Norwegian Atlantic salmon comes from the computer files maintained by the NMFS and is also available in the U.S. Import for Consumption published by the Bureau of Census, Department of Commerce. The price of Norwegian Atlantic salmon is derived from dividing the value of imports on an FOB basis by the quantity. The exvessel price of chinook salmon in the state of Washington (reported in Fishery Market News by the NMFS) was treated as the price of the substitute for the Norwegian Atlantic salmon. The exvessel price of chinook salmon was used in the estimation of the wholesale demand because of a lack of published information on the wholesale price of chinook. The wholesale price used by Riley and reported in the Seafood Price-Current was and is still not available to the authors. The data for the exvessel price of chinook before 1983 was sporadic, and the January price has been missing in Fishery Market News; data used in this study, therefore, covers eleven months for each year from 1983 through 1986.

The CIF value of the imported Norwegian Atlantic salmon up to August 1986 is available from U.S. Imports for Consumption. The FOB price is used in order to have four more observations. In the future, use of the CIF price would be more desirable. In total, there are 44 monthly observations out of four years used to estimate the U.S. demand for Norwegian Atlantic salmon. The wholesale price index for food and feeds was used to derive the real prices and income from their nominal counterparts. Income and the wholesale price index of food and feeds are from Survey of Current Business published by the Department of Commerce.

Population (available from Population Estimates and Projections, Department of Commerce) was used to generate per capita consumption and income. Because the monthly population figures for the last six months of 1986 are still unavailable, the monthly population for the sample period was fitted by a linear time trend model which has a coefficient of determination (R^2) close to 1, and the predicted population figures were treated as the actual population. Because all of the variables are divided by their respective geometric means to facilitate the estimation of Box-Cox flexible functional forms, units of measurement are not given here. However, elasticities will be provided.

Preliminary estimation suggested that the interactive terms of SEASON and AP and KP do not affect the demand for Atlantic salmon. Further, the log-linear model performs better than the linear form. Because the selection of functional form is an important issue in econometric modeling, the flexible functional form introduced by Box and Cox (1964) was estimated with the following results:

$$AQ_t^* = \underset{(5.16)}{0.22} - \underset{(2.86)}{1.31}AP_t^* + \underset{(1.49)}{0.14}KP_t^* + \underset{(4.55)}{3.78}Y_t^* + \underset{(5.22)}{0.51}AQ_{t-1}^* - \underset{(5.86)}{0.38}SEASON \qquad (2)$$

where the numbers in parentheses are t statistics, and an asterisk means a power transformation, for instance $AQ_t^* = (AQ_t^{0.36} - 1)/0.36$. Other variables with an asterisk are also transformed by the same power, i.e., 0.36.

The value of the power transformation (i.e., 0.36) together with the estimated coefficients generate the maximum log-likelihood value of the Box-Cox flexible functional form. The R^2 and adjusted R^2 are 0.89 and 0.88, respectively. The above results were obtained by correcting for the first-order autocorrelation with a rho value of -0.36 whose t ratio is 2.53.

The above results show that the signs of all estimates are consistent with a priori theoretical expectations. Fresh chinook is found to be a substitute for cultured Atlantic salmon with a t statistic of 1.49 so that the coefficient is different from 0 at an 8% significance level on a one-tailed test. All other estimates are different from 0 at a 1% significance level. Therefore, empirical results are deemed satisfactory.

Because previous consumption of Atlantic salmon does affect the present consumption, both short-run and long-run demand elasticities can be calculated. The short-run elasticities for own-price, cross-price, and income when evaluated at the mean values are -1.22, 0.13, and 3.5, respectively. Long-run elasticities are -2.48, 0.27, and 7.12, respectively. These elasticities appear to be plausible. Norwegian Atlantic salmon is considered a luxury good in the U.S., meaning that its demand is highly sensitive to consumers' income. The U.S. demand for cultured Atlantic salmon is price elastic, implying that a 1% decrease in its price will induce more than 1% (2.48% to be exact in the long run) increase in consumption (import).

Fresh chinook is a substitute for cultured Atlantic salmon, but the degree of substitution should not be characterized as strong since the long-run cross-price elasticity is only 0.27. The cross-price elasticity is a measurement of competition among goods. Usually, two goods are considered to be close substitutes (strong competitors) when their cross-price elasticity exceeds 1. Since these two species of salmon are substitutes, imports of cultured Atlantic salmon will depress the short-run earnings of chinook fishermen. If different species of Pacific salmon are substitutes among themselves, fishermen fishing Pacific salmon for the fresh market will be adversely affected by imports of Atlantic salmon to a greater extent, ignoring the expansion effect of imports of cultured Atlantic salmon on the market for Pacific salmon. It is important to point out that additional demand analysis is still needed to estimate the overall (dynamic) effect of imported salmon on the Pacific salmon market.

Supply of Norwegian Atlantic salmon to the U.S.

France, the United States, West Germany, and Denmark are major importers of Norwegian cultured Atlantic salmon. While imports to all these countries have increased during the period from 1982 through 1986, the U.S. experienced the largest increase.

Even though the U.S. has emerged as the leading importer by an increasing margin and the total supply of Norwegian salmon may well be fixed in the short run, it is likely that the Norwegian supply to the U.S. will be affected by the price offered by the U.S. consumers relative to that offered by consumers of other countries. In other words, the total Norwegian supply may be fixed in the short run, but shipments of the fixed supply to different export markets are possibly determined by prices in these markets. If the Norwegian supply of salmon to the U.S. is indeed responsive to prices, the empirical results of the U.S. demand analysis using single equation models may suffer from a simultaneous equation bias. Therefore, it is important to check whether or not the price variable in the U.S. demand function can be treated as exogenous.

The exogeneity of the price of Norwegian Atlantic salmon is tested by estimating a single equation model which hypothesizes that the Norwegian supply to the U.S. is affected by the U.S. price, prices of other export markets, the total supply of Norwegian Atlantic salmon, and the previous supply to the U.S. If this supply equation is significant, then the price of Atlantic salmon should be treated as endogenous in a simultaneous supply and demand model. The previous supply is included to reflect a partial adjustment process due to the use of monthly data--the same justification for including the consumption lag in the demand model. The model can be expressed as follows:

$$Q_{us,t} = g(P_{us,t}, P_{row,t}, S_t, Q_{us,t-1}) \qquad (3)$$

where Q_{us} is the supply to the U.S.; P_{us} is the price of the supply to the U.S.; P_{row} is the price paid by other countries; S is the total supply; and subscripts t and t-1 are the current and previous months, respectively.

It is expected that $P_{us,t}$ has a positive effect and $P_{row,t}$ has a negative effect on $Q_{us,t}$. When the U.S. offers a higher relative price, Norway will ship more of its production to the U.S. than to other countries. As the total fixed supply is increased, more will be shipped to the U.S. Therefore, S_t should have a positive coefficient not exceeding 1. The previous shipment to the U.S. should have a coefficient between 0 and 1, measuring the speed of adjustment toward an equilibrium.

As discussed before, monthly statistics on the supply quantity and value (FOB) of Norwegian Atlantic salmon to the U.S. are available from the computer files maintained by the NMFS. By dividing the FOB value by the quantity, the U.S. price in U.S. dollars is available on a FOB basis. Data on Norwegian exports of Atlantic salmon from 1983 through 1985 was provided by Johan Muri of the Norwegian Export Committee for Fresh Fish. This export data has quantity shipped by countries, but the FOB value is given only as a total for all destinations. By using the data from the NMFS and the Norwegian Export Committee for Fresh Fish together with the monthly exchange rates between the U.S. dollar and the Norwegian Kroner, the U.S. price (P_{us}) and the price of the rest of world (P_{row}) can be calculated in terms of the Norwegian Kroner. (Exchange rates were collected from various issues of International Financial Statistics published by the International Monetary Fund.)

Monthly data from 1983 through 1985, 36 observations in total, were used to estimate the supply model. The Box-Cox flexible functional form produces the following results:

$$Q^*_{us,t} = \underset{(0.27)}{0.01} + \underset{(2.30)}{1.31}P^*_{us,t} - \underset{(3.93)}{3.48}P^*_{row,t} + \underset{(2.36)}{0.40}S^*_t + \underset{(8.57)}{0.72}Q^*_{us,t-1} \qquad (4)$$

where numbers in parentheses are t values, and an asterisk means the variable is transformed by a power of 0.58.

The above results were obtained after correcting for the first-order autocorrelation with a rho value of -0.32 whose t value is 2.0. R^2 and adjusted R^2 are 0.81 and 0.79, respectively. T statistics indicate that all of the independent variables do affect the supply of cultured Atlantic salmon from Norway to the U.S. All of the estimated coefficients have a sign consistent with a priori theoretical expectations.

The short-run elasticities, evaluated at their mean values, for P_{us}, P_{row}, and S are 1.18, -3.12, and 0.40, respectively. When the U.S. price increases (decreases) by 1%, the U.S. imports increase (decrease) by 1.18% in the short run, all else being equal. If the rest of the world bids up its price by 1%, in the short run it will receive 3.12% more cultured salmon from Norway. When the Norwegian supply of cultured Atlantic salmon is increased by 1%, the U.S. will increase its imports by 0.40%. In the long run, the elasticities of P_{us}, P_{row}, and S are 4.28, -11.32, and 1.34, respectively.

The above results suggest that the U.S. imports of cultured salmon will continue rising as the Norwegian production is expanded. Economic and political factors affecting the demand and price paid for cultured salmon are important in determining Norwegian shipments of cultured salmon to export markets. An increase in U.S. income relative to other importers will further boost the U.S. share of Norwegian exports. A poor harvest of chinook salmon is expected to bid up the price of chinook, but the price increase would be larger if the cultured salmon was unavailable.

The significant results summarized in equation (4) point up an important econometric issue for modeling the market of cultured Atlantic salmon. Since both the demand for and the supply of cultured Atlantic salmon are responsive to price, results shown in equations (2) and (4) may be biased. Even though the single equation approach does not always perform worse than the simultaneous equation approach, it is important to check to see if our understanding of the market can be improved by building a simultaneous equation model. This issue is further elaborated upon in the discussion of future research needs.

The French salmon market

In the French market, cultured Atlantic salmon imported from Norway is in both fresh and frozen forms, and the bulk of Pacific salmon imported from the U.S. and Canada is in frozen form; in France, therefore, end uses of Atlantic salmon and Pacific salmon are likely to be different. In the U.S. fresh and frozen chinook is sold against the fresh Norwegian Atlantic salmon. Hence the relationship between cultured Atlantic salmon and chinook in the U.S. may differ from that in the French market. Therefore, we would not necessarily expect a priori the same results in the two markets. This issue can be investigated using either of the two econometric models as discussed below.

The demand model estimated previously for the U.S. is also applicable to the French market. In other words, the French demand for cultured Atlantic salmon can be hypothesized as being affected by the prices of cultured Atlantic salmon and chinook, French income, previous consumption, and seasonal dummy variables. The second model uses the market share approach in which the share of chinook in the French Atlantic and chinook combined market is hypothesized as being affected by the price ratio between chinook and Atlantic salmon and the previous market share. This latter model was estimated in this paper.

The market share model was used by Sirhan and Johnson (1971) and Meilke and Griffith (1981) to study the international cotton market and the soybean and rapeseed oil markets, respectively. This approach can be utilized to examine whether or not these two species of salmon are substitutes in the French market. If they are, the demand own-price elasticity and cross-price elasticity but not the income elasticity can be calculated. The market share model is specified as follows:

$$SHARE_t = g(\ PRICE_t,\ \ SHARE_{t-1},\ \ D) \tag{5}$$

where SHARE denotes the share of Norwegian cultured Atlantic salmon in the French market. This is calculated by dividing the total imports of the Atlantic salmon by the total imports of Atlantic and chinook salmon; PRICE denotes the ratio of Atlantic salmon price over chinook price, and D is a dummy variable which is set to 1 during the chinook fishing season and 0 otherwise.

If these two species of salmon are substitutes, an increase in the price of chinook will decrease the French imports of chinook but increase French imports of Atlantic salmon. Therefore, the variable PRICE is expected to have a negative sign. The treatment of the lagged dependent variable as an independent variable captures the partial adjustment effect. The lagged dependent variable should have a coefficient falling between 0 and 1. The share of chinook in the total market should become larger during the chinook season, and the variable D should have a negative coefficient.

Both the U.S. and Canada export chinook to France, so the French imports of chinook include shipments from both countries. The Canadian value of monthly exports were converted into dollars and combined with the U.S. value of monthly exports and then aggregated quarterly. This aggregation is necessary because neither the U.S. nor Canada exported chinook to France for all twelve months within a year. The quarterly value of chinook shipments were then divided by the quarterly quantity in order to derive the chinook price. The Norwegian price was converted into dollars and then divided by chinook price to generate the variable PRICE. U.S. export statistics are from Exports for Consumption published by the Bureau of Census, Department of Commerce. Canadian data come from Trade of Canada: Exports by Commodities published by Statistics Canada.

As stated above the bulk of chinook shipped to France is in frozen form, but Norway ships both fresh and frozen Atlantic salmon to France. Two models were specified in the market share analysis. One of them looks at the competition between cultured (fresh and frozen) Atlantic salmon and chinook, and the other examines the relationship between frozen Atlantic and chinook salmon. Both models were estimated by using the Box-Cox flexible functional form. Since the results for both models are similar, only the model combining both fresh and frozen Atlantic salmon is presented:

$$SHARE^*_t = \underset{(4.78)}{0.82} + \underset{(0.84)}{0.34}PRICE^*_t + \underset{(6.0)}{0.61}SHARE^*_{t-1} - \underset{(7.13)}{0.86}D \qquad (6)$$

where an asterisk denotes a power transformation using the value of 1.62.

Results shown in equation (6) were obtained after correcting for the first-order autocorrelation with a rho value of -0.5. R^2 and adjusted R^2 are 0.81 and 0.76, respectively. The estimated coefficients of $SHARE_{t-1}$ and D have the expected signs and high t statistics. The coefficient of the price variable suggests that as the price of Atlantic salmon is increased relative to the chinook price, France will import more Atlantic salmon than chinook. This positive coefficient is obviously counter-intuitive but has a low t statistic and so is not statistically significant at any reasonable level of confidence. Therefore, it is tentatively concluded that Atlantic and chinook salmon are independent goods rather than substitutes. This conclusion is tentative because the price of Atlantic salmon as calculated is for shipments to all countries other than the U.S., not the true price paid by France. (A better estimate of the French market would require actual French import prices.) Since other European countries, such as West Germany and Denmark, do import large quantities of Atlantic salmon, it would be better to investigate the relationship between chinook and cultured Atlantic salmon in the European market as a whole using the above Atlantic salmon price.

Summary and Future Research Needs

Three single equation models were presented in this paper. The first model is for the U.S. demand for cultured Atlantic salmon from Norway. The U.S. demand for cultured Atlantic salmon is found to be price and income elastic, and Atlantic salmon is a substitute for fresh chinook. The second model deals with the supply of Norwegian Atlantic salmon to the U.S. It is found that the supply to the U.S. is affected by the prices paid by the U.S. and other importers of Norwegian Atlantic salmon. Total Norwegian production and previous supply to the U.S. also determine, in part, the current supply. Finally, a market share model was estimated to investigate the relationship between imported cultured Atlantic and wild chinook in France. Results suggest that these two species of salmon are not competitors in France.

Because the U.S. demand for and supply of Atlantic salmon are responsive to prices, the results of the demand and supply single equation models are likely to be biased. A simultaneous equation model is needed to check to see if the simultaneous equation bias can be removed from the single equation results. Such a model is discussed here.

United States, France, West Germany, and Denmark are the major importers of Norwegian Atlantic salmon. Ideally, a demand equation should be specified for each importer in the model. Then the model will include at least eight behavior equations (four endogenous quantity and four endogenous price variables) and hence requires substantial modeling efforts realizing the existence of autocorrelation problems and the importance of functional form. Since our knowledge of the markets for cultured Atlantic salmon is still primitive, the immediate research agenda may initially focus on the U.S. market. A simplified simultaneous equation model of three behavior equations and two identity equations is, therefore, proposed here:

$$D_{us,t} = f(P_{us,t}, P^*_{us,t}, D_{us,t-1}, X_{us,t})$$

$$D_{row,t} = g(P_{row,t}, P^*_{row,t}, D_{row,t-1}, X_{row,t})$$

$$S_{us,t} = h(P_{us,t}, P_{row,t}, S_{tot}, S_{us,t-1})$$

$$D_{us,t} = S_{us,t}$$

$$D_{us,t} + D_{row,t} = S_{tot}$$

where D_{us} and D_{row} are the demands for Norwegian Atlantic salmon in the U.S. and the rest of world, respectively; S_{us} and S_{tot} are the supplies to the U.S. and the whole world, respectively; P_{us} and P_{row} are the prices paid for Norwegian Atlantic salmon by the U.S. and the rest of world, respectively; P^*_{us} and P^*_{row} are prices of substitutes for Norwegian Atlantic salmon in the U.S. and the rest of world, respectively; and X_{us} and X_{row} are other demand shifters (such as income, seasonality, etc.) in the U.S. and the rest of world, respectively. D_{us}, D_{row}, S_{us}, P_{us}, and P_{row} are endogenous variables. The model is complete because there are five equations and five endogenous variables.

Since the U.S. Pacific salmon industry needs to know the impacts of Atlantic salmon imports on the demand for their products, the simultaneous equation model can be expanded to provide more information. In the single equation demand equation, chinook is found to be a substitute for Atlantic salmon. Therefore, the demand for and the price of chinook should be affected by imports of Atlantic salmon. Since landings of fish are primarily determined by fishing regulations and environmental conditions, the price dependent model for estimating the demand for chinook is more likely to produce satisfactory results. Therefore, an equation can be added to the model given above--an equation in which the price of chinook is hypothesized to be determined by the landings of chinook, imports of Atlantic salmon, and other shifters. Data problems and other difficulties associated with the estimation of the simultaneous equation model will be discussed at the end of this section.

As mentioned in the introduction, aquaculturists argue that imports and domestic production of Atlantic salmon have a positive overall effect on the demand for Pacific salmon. This assertion seems logical, but it is difficult to analyze. This is because the overall effect is a dynamic phenomenon which can, theoretically, be analyzed by including a time trend or the cumulated imports of Atlantic salmon to capture the expansion of the chinook market over time. But the expansion effect, if any, caused by the imports of Atlantic salmon will be mixed with the effect of consumers' increasing concerns about health which has consumers switching from red meat to fresh/frozen fish and is not an expansion effect. If a time trend variable is included in the demand equation for chinook and is found to have a positive effect on demand, it would be difficult to separate this expansion of the market from the correlated change in tastes and preferences. But as long as the negative effect of the imports (i.e., the coefficient of the imports) is greater than positive effect measured by the time trend (or cumulated imports) variable, it is clear that those who make a living in the dealing of fresh chinook are damaged by the imports of Atlantic salmon.

The above discussion addresses some of the areas for future research in the salmon market. But possible econometric models for accomplishing these research tasks are proposed without any discussion of the data problems likely to be encountered in the empirical analysis. A brief discussion of possible data problems is, therefore, in order.

First, there is a problem in measuring the demand shifters for the rest of world in estimating its demand for Atlantic salmon. Basically, it needs to be decided which income and substitute prices to use. A possible solution is to use individual country's imports as weights in deriving composite income and price variables.

Second, monthly or quarterly data has to be used to allow for enough degrees of freedom in the empirical analysis. It can be time-consuming to collect the monthly and quarterly information for European importers, especially the prices of substitutes if chinook and other Pacific salmon are not substitutes for Atlantic salmon.

Third, the exvessel price of chinook is missing for the month of January. Because the exvessel price of chinook in Washington varies substantially from December to February, it is difficult to interpolate the January price. The use of quarterly data can also be troublesome in this regard. Wholesale price is available, as discussed above, but the quantity traded at the wholesale level is missing. Even though the monthly landings of chinook for Washington are available (except January) from Fishery Market News, landings of other states (Alaska, Oregon, and California) will likely affect the exvessel price of chinook in Washington. Alaska is the major producer of Pacific salmon, but about 97% of Alaskan landings are processed in non-fresh form (Rogness and Lin). Since Atlantic salmon is deemed a substitute for <u>fresh</u> Pacific salmon, this data problem may not be too severe, but it is nevertheless a legitimate concern.

Fourth, an additional chinook exvessel price problem may come from the fact that during the off-season (November to May) chinook exvessel prices reflect troll-caught chinook, while prices for June through October reflect only a small proportion of troll-caught chinook (Inveen 1987). Since troll-caught chinook prices reflect a different product than nontroll-caught chinook, some discrepancies may develop here.

References

Aquaculture Project Group. "The Outlook for Salmon and Shrimp Aquaculture Products in World Markets." U.S. Dept. of Commerce, NOAA, NMFS Washington D.C., 1985.

Box, G.E.P. and D.R. Cox. "An Analysis of Transformations." J. of the Royal Stat. Soc. ser. B. 26(1964):211-43.

Canada, Statistics Canada. Trade of Canada: Exports by Commodities. Ottawa: Canadian Bureau of Statistics, various issues.

DeVoretz, D. "An Econometric Demand Model for Canadian Salmon." J. of Cana. Ag. Econ. 30(1982):49-60.

International Monetary Fund. International Financial Statistics. Washington D.C., various issues.

Inveen, Daniel C. "The Aquaculture Industry in Washington State: An Economic Overview." Department of Trade and Economic Development, Washington State. May 1987.

Kabir, M. and N.B. Ridler. "The Demand for Atlantic Salmon in Canada." J. of Cana. Ag. Econ. 32(1984):560-68.

Lin, B. H. "An Econometric Analysis of Salmon Markets." Proceedings of the Second Conference of the IIFET, OSU Sea Grant Pub. ORESU-W-84-001. Corvallis, Oregon, 1984.

Lin, B.H. "The Demand for Atlantic Salmon in Canada: Issues of Functional Form and Parameter Stability." Unpublished paper. Department of Ag. Econ, Univ. of Idaho, Moscow, Idaho, 1986.

Meilke, K.D. and G.R. Griffith. "An Application of the Market Share Approach to the Demand for Soybean and Rapeseed Oil." Euro. Rev. of Ag. Econ. 8(1981):85-97.

Riley, P.L. An Economic Analysis of the Market for Atlantic Salmon Aquaculture. Ph.D. Dissertation. Department of Resource Economics, Univ. of Rhode Island. Kingston, Rhode Island, 1986.

Rogness, R.V. and B.H. Lin. The Marketing Relationship between Pacific and Pen-Raised Salmon: A Survey of U.S. Seafood Wholesalers. Alaska Sea Grant Report 86-2. Fairbanks, Alaska, 1986.

Sirhan, G. and P.R. Johnson. "A Market Share Approach to the Foreign Demand for U.S. Cotton." Amer. J. of Ag. Econ. 53(1971):593-599.

U.S. Dept. of Commerce. Population Estimates and Projections. Washington, D.C. Series P-25. Various issues.

U.S. Dept. of Commerce. Survey of Current Business. Washington, D.C. Various issues.

U.S. Dept. of Commerce. U.S. Exports for Consumption. Bureau of Census. Various issues.

U.S. Dept. of Commerce. U.S. Imports for Consumption. Bureau of Census. Various issues.

U.S. Dept. of Commerce. Fishery Market News. NOAA, NMFS, Seattle, Washington. Various issues.