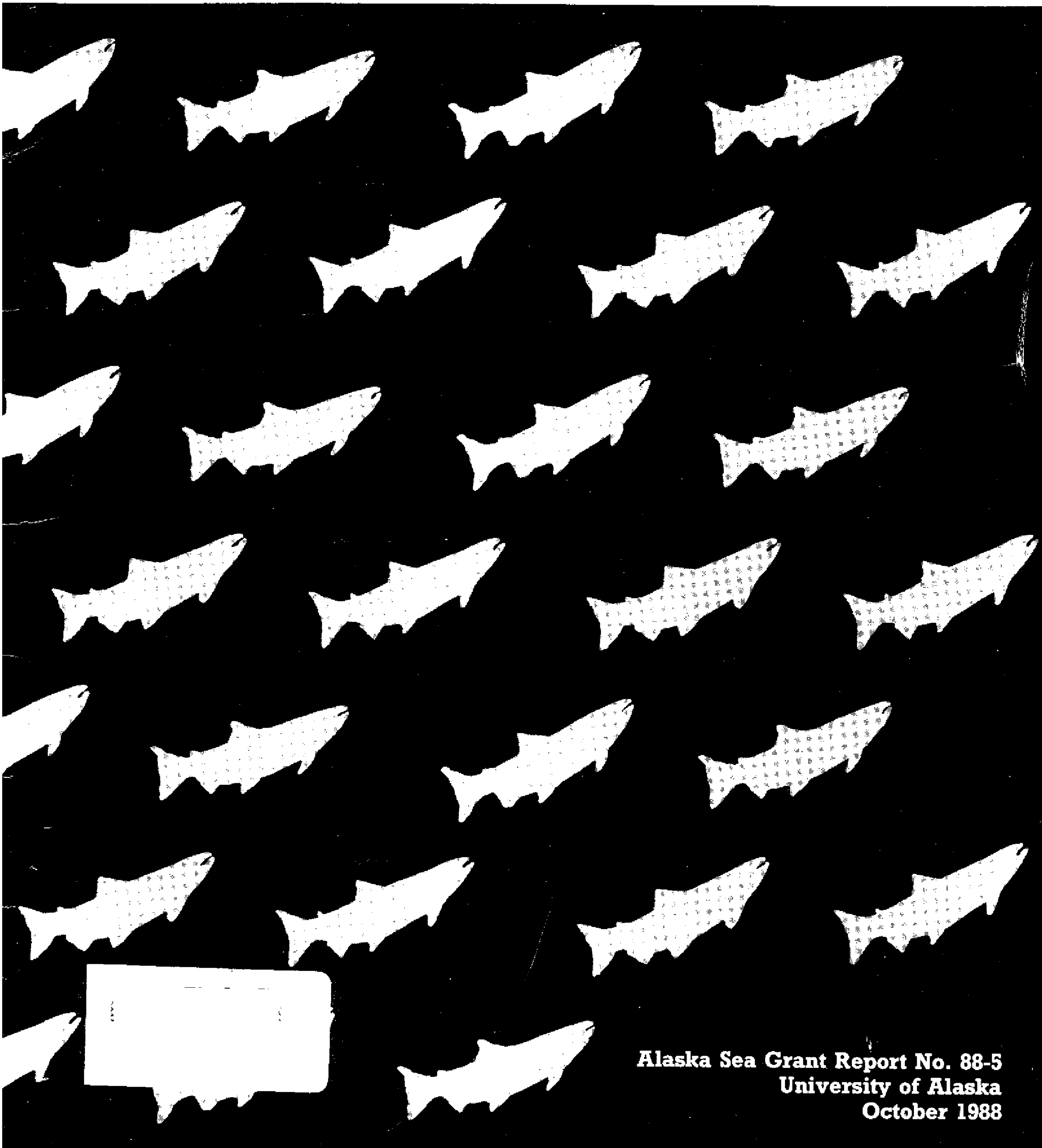
An Econometric Analysis of Atlantic Salmon Markets in the United States and France

Biing-Hwan Lin and Mark Herrmann



Alaska Sea Grant Report No. 88-5
University of Alaska
October 1988

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Elmer E. Rasmuson Library Cataloging-in-Publication Data

Lin, Biing-Hwan.
An econometric analysis of Atlantic salmon markets in the United States and France.

(Alaska Sea Grant report ; no. 88-5)

1. Atlantic salmon--United States--Marketing--Mathematical models. 2. Atlantic salmon--France--Marketing--Mathematical models. I. Herrmann, Mark. II. Alaska Sea Grant College Program. III. Title. IV. Series: Alaska Sea Grant report ; 88-5.

HD9469.S22L562 1988

ACKNOWLEDGEMENTS

This research and publication was supported by the Alaska Sea Grant College Program, cooperatively supported by the U.S. Department of Commerce, NOAA Office of Sea Grant and Extramural Programs, under grant number NA86AA-D-SG041, project numbers R/14-09 and A/75-01, and by the University of Alaska with funds appropriated by the state. The cover design is by Karen Stomberg and Sue Keller.

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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 faced 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 endeavors abroad. Meanwhile, the recent surge in the demand for highly valued seafood has stimulated interest in culturing of fish. World farmed salmon production has increased and is expected to continue to increase, due to the dramatic success in the Norwegian farming of Atlantic salmon and the proliferation of salmon farming worldwide (Table 1).

Norway produced 28,655 metric tons (mt) of Atlantic salmon in 1985 and plans to increase production to 100,000 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 United States, the leading consumer of cultured salmon, has been on the increase, it is likely that the increase in supply will eventually outrun the increase in demand and hence force prices to drop. It is obvious that those who have invested and those who contemplate investing in salmon farming ventures need some information on the future demand for and price of Atlantic salmon.

In 1984 the United States replaced France as the leading importer of Norwegian cultured Atlantic salmon. In 1985 the United States bought 26 percent of Norwegian exports of fresh and frozen Atlantic salmon which amounted to more than 53 million pounds. The U.S. import volume and price of Norwegian Atlantic salmon are shown in Figures 1 and 2. It is expected that the U.S. imports of Norwegian Atlantic salmon will continue increasing as Norwegian production rises. Furthermore, those who are producing cultured salmon in other locations also hope to sell most of it in the United States. This rapid increase in the importation of cultured salmon has raised great concerns within the U.S. Pacific salmon industry.

Pacific salmon fishermen are concerned about the impacts of increased imports on the price of their catch. This concern is acute because salmon fishing permits in many areas are very expensive. The right to fish is usually transferable, and the market value of the permit is determined by the expected earnings from fishing. Therefore, the impact of Atlantic salmon imports on the ex vessel price of Pacific salmon is a major concern in salmon fishermen's exit and entry decisions.

Because of the uncertain effect of cultured salmon production on the

Table 1. World farmed salmon production in metric tons live weight, actual: 1984-1986, projected: 1987-1990.

Country	1984	1985	1986	1987	1988	1989	1990
EUROPEAN ECONOMIC COMMUNITY							
France	50	60	200	200	200	200	200
Ireland	385	722	1,500	2,210	4,520	6,630	10,100
U.K.	3,912	6,921	10,338	13,950	15,000	20,000	25,000
TOTAL	4,447	7,853	12,188	16,559	20,020	27,280	35,900
EUROPE, NON-ECONOMIC COMMUNITY							
Faroe Islands	116	470	1,370	4,800	4,800	7,100	9,000
Iceland	107	91	123	800	1,750	2,500	5,000
Norway	22,300	28,655	45,675	53,000	74,000	74,000	100,000
Sweden	20	80	300	400	800	1,000	1,000
TOTAL	22,637	29,396	47,568	59,100	81,450	84,700	115,100
NORTH AMERICA (Canada)							
Atlantic	200	300	400	800	1,600	3,200	5,000
Pacific	107	120	600	3,200	8,400	14,600	23,000
TOTAL	307	420	1,000	4,000	10,000	17,800	28,000
OTHER							
Chile	109	500	1,144	1,720	7,522	15,410	17,000
Japan	5,049	6,430	8,000	13,000	15,000	17,000	19,000
New Zealand	10	250	500	1,000	1,500	2,000	3,000
TOTAL	5,168	7,180	9,644	15,720	24,022	34,410	39,000
GRAND TOTAL	32,559	44,849	70,400	95,379	135,492	164,190	218,000

Source: National Marine Fisheries Service, *World Salmon Aquaculture,* 1986-1987. Office of International Affairs, Department of Commerce, October 30, 1987.

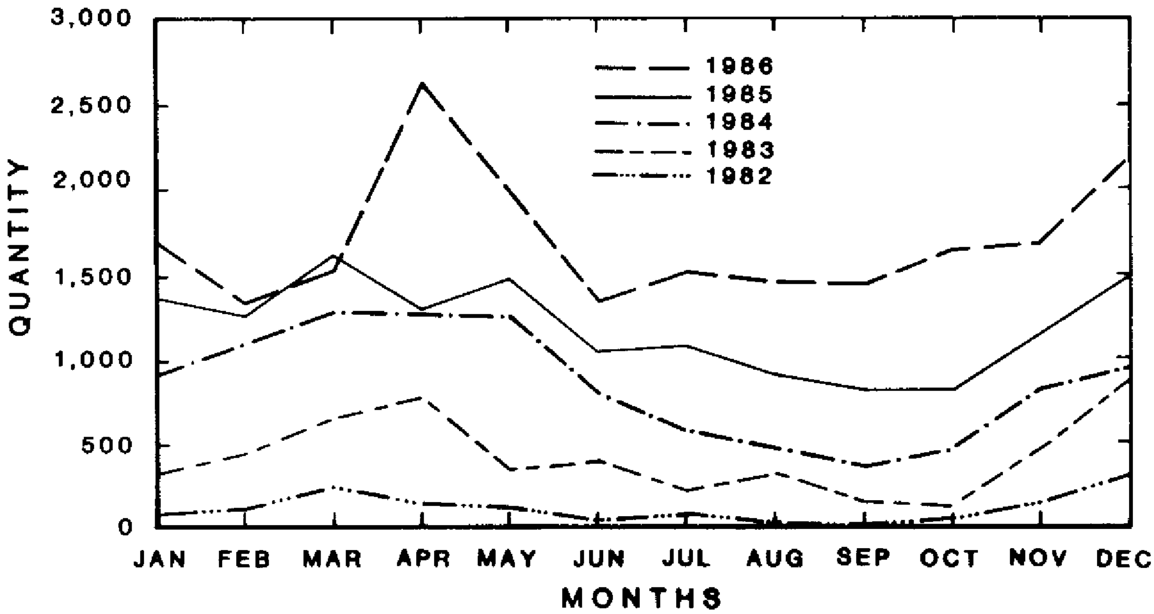

Figure 1. Quantity of Norwegian exports of farmed Atlantic salmon to the United States, in thousands of pounds.

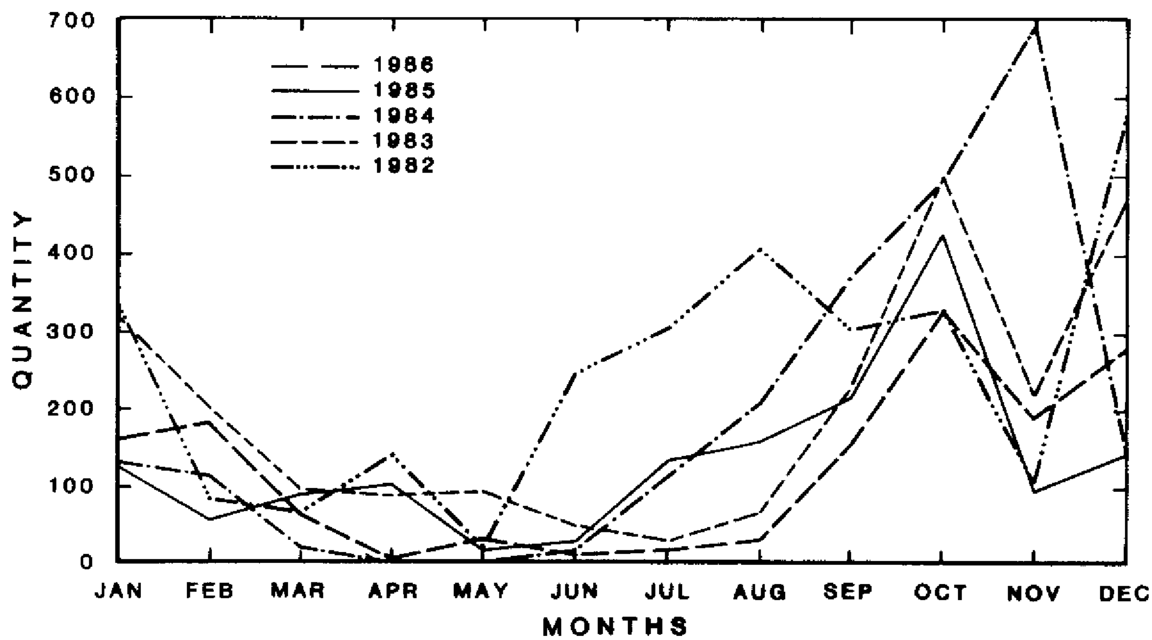

Figure 2. Price of Norwegian exports of farmed Atlantic salmon to the United States (U.S. dollars).

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 cultured salmon provides high quality products year round and hence expand the market for fresh and frozen Pacific salmon. In other words, as fresh salmon becomes available outside the Pacific salmon season, there is an increase in the number of consumers and purchase frequency of Pacific salmon during the season. 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 highly unlikely that these species of salmon are consumed together.

It is 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 exporter-importers of salmon products will also certainly be affected by imports of Atlantic salmon. The allocation of salmon landings between canned and non-canned processing was found to be affected by the prices of the two product forms (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.

An increase in the exports of cultured salmon by Norway is likely to have an impact on both the demand for U.S. salmon exports and the demand for domestic Pacific salmon. However, because of different 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. The market in France is important to consider, since France is one of the leading importers of both Norwegian cultured Atlantic salmon and Pacific salmon from the United States and Canada. French monthly imports of salmon are shown in Figures 3 and 4.

While the imports of cultured Atlantic salmon may affect 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

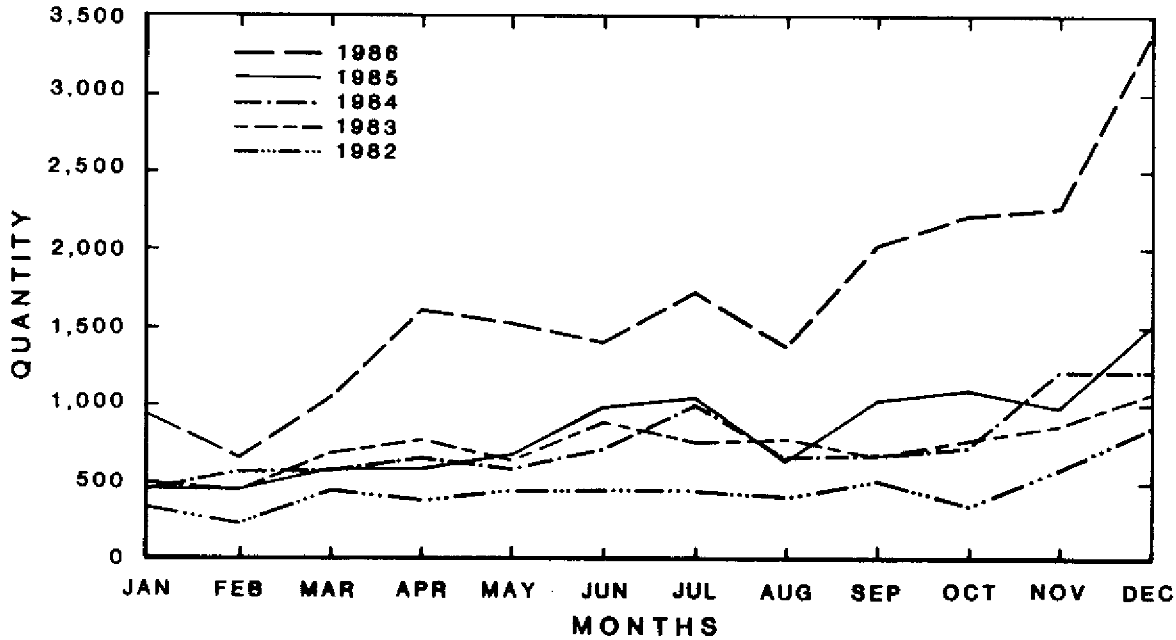

Figure 3. Quantity of Norwegian exports of farmed Atlantic salmon to France, in thousands of pounds.

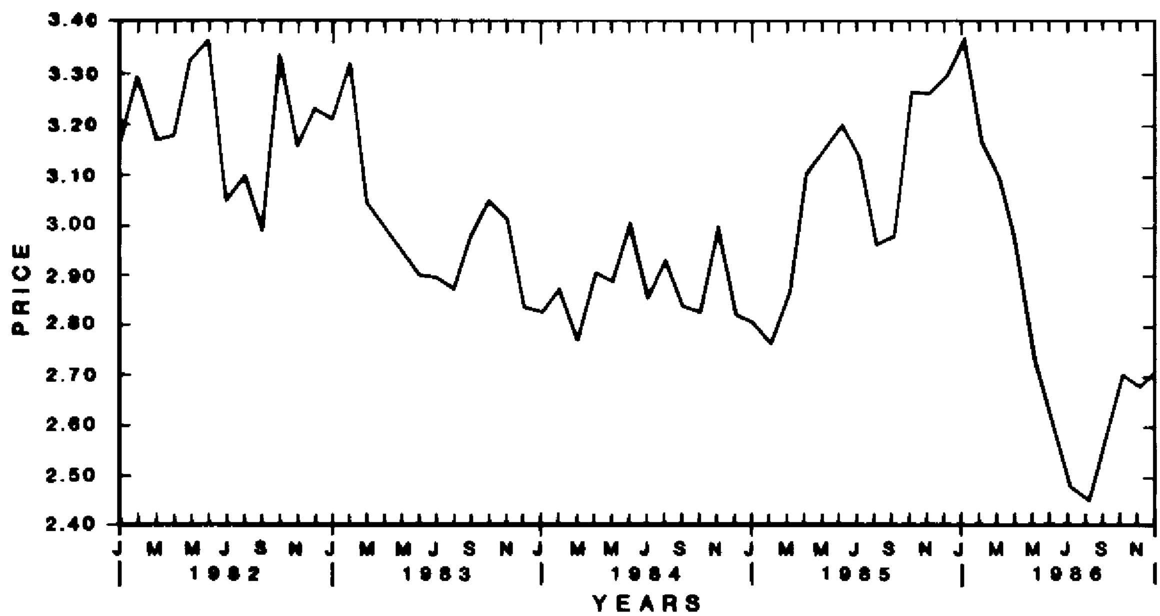

Figure 4. Quantity of North American exports of Chinook salmon to France, in thousands of pounds.

price of Pacific salmon is affected by imports of Atlantic salmon. Allocation of salmon stock between commercial and sport fishermen should be revised for the same reason. Public and private salmon hatcheries also need to consider the possible changes in their revenues caused by the imports of cultured Atlantic salmon. 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 to provide answers to the concerns of the U.S. Pacific salmon fishing industry. Econometric models are specified in this paper to address three major concerns. First, what is the marketing relationship between cultured Atlantic and wild Pacific salmon? Are they substitutes? We need to know which of the five species of Atlantic salmon 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 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.

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 and frozen Atlantic salmon, only the studies of fresh and frozen salmon are reviewed here.

DeVoretz (1982) estimated the Canadian demand for canned salmon and fresh and 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 and frozen sector are disappointing in that they are inconsistent with a priori theoretical expectations. Lin (1984) estimated the domestic and export demand for Canadian canned salmon and North American (United States and Canada combined) canned and fresh and 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 and frozen salmon produced in the United States and Canada were disappointing once again. Because there are no published data on the production of fresh and frozen salmon in the United States, 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. According to their results fresh and frozen wild Atlantic salmon is a luxury good on the Canadian market with income elasticity of around 4.0 and price elasticity in the neighborhood of 10. However, they failed to identify substitute goods for Atlantic salmon. Lin (1986) re-estimated the Canadian demand for fresh and 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 produced unstable estimates. The own-price, income, and cross-price elasticities were found to be 12.5, 8.3, and 4.2, respectively. Because the demand characteristics for wild Atlantic salmon and cultured Atlantic salmon are not necessarily similar, 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 and 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 information to assist the U.S. salmon industry.

MODELS AND EMPIRICAL RESULTS

In this report we present the 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 United States; 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 United States. 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 U.S. demand for cultured Atlantic salmon follows the economic theory in which 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 effect of the heaviest landings of Pacific salmon on the demand for Norwegian Atlantic salmon. Therefore, the demand function was specified as follows:

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

where AQ is the per capita consumption (import) of Norwegian Atlantic salmon; AP is the real price of Atlantic salmon; KP is the real ex vessel 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 and other things remain constant, 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 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 luxury goods. 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 the data is in order. The sample period covered is from January 1982 through August 1987. Monthly data are used to analyze the demand for and supply of Norwegian Atlantic salmon in the United States, while quarterly data are used to analyze the French market. The monthly import data on Norwegian Atlantic salmon are provided by the Statistisk Sentralbyra (Central Statistics) of Norway. The price of Norwegian Atlantic salmon is derived from dividing the value of imports on a FOB basis by the quantity and converting the price to U.S. dollars. The ex vessel price of chinook salmon in the state of Washington (from the Washington State Department of Fish and Game) was treated as the price of the substitute for the Norwegian Atlantic salmon. The ex vessel 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 CIF value of the imported Norwegian Atlantic salmon up to February 1987 is available from *U.S. Imports for Consumption*. The Norwegian FOB price is used in order to have four more observations. In total, there are 68 monthly observations out of six 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 two months of the sample period are still unavailable, the monthly population for these two months 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:

$$(2)\quad \underset{}{AQ^*_t} = \underset{(7.60)}{0.44} - \underset{(-4.67)}{1.97AP^*_t} + \underset{(1.30)}{0.14KP^*_t} + \underset{(2.79)}{4.79Y^*_t} + \underset{(2.80)}{0.30AQ^*_{t-1}} - \underset{(-7.32)}{0.54SEASON}$$

where the numbers in parentheses are t statistics, and an asterisk means a power transformation, e.g., $AQ^*_t = (AQ_t^{0.53} - 1)/0.53$. Other variables with an asterisk are also transformed by the same power, i.e., 0.53.

The value of the power transformation (i.e., 0.53) 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 0.88 and 0.87, respectively. The above results were obtained by correcting for the first-order autocorrelation with a rho value of -0.22 whose t ratio is 1.69.

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 1.30 so that the coefficient is different from 0 at a 10 percent significance level on a one-tailed test. All other estimates are different from 0 at a 1 percent significance level.

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 -1.44, 0.11, and 3.61, respectively. Long-run elasticities are -2.05, 0.16, and 5.16, respectively. These elasticities appear to be plausible. Norwegian Atlantic salmon is considered a luxury good in the United States, 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 percent decrease in its price will induce more than 1 percent (2.05 percent 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 0.16. 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 United States

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

United States experienced the largest increase.

Even though the total supply of Norwegian salmon may well be fixed in the short run, it is likely that the Norwegian supply to the United States will be affected by the price offered by U.S. consumers relative to that offered by consumers in 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 United States 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 United States 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 United States. 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:

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

where Q_{us} is the supply to the United States; P_{us} is the price of the supply to the United States in Norwegian kroner; P_{row} is the price paid by other countries in Norwegian kroner; 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 exports to the United States than to other countries. As the total fixed supply is increased, more will be shipped to the United States. Therefore, S_t should have a positive coefficient not exceeding 1. The previous shipment to the United States should have a coefficient between 0 and 1, measuring the speed of adjustment toward an equilibrium.

Data on Norwegian exports of Atlantic salmon are provided by the Central Statistics of Norway. These export data have quantity and value shipped by countries. The U.S. price (P_{us}) and the price of the rest of the world (P_{row}), derived from total Norwegian exports less U.S. exports, are calculated in terms of Norwegian kroner. Exchange rates were collected from various issues of *International Financial Statistics* published by the International Monetary Fund to derive P_{row}.

Monthly data from January 1982 through August 1987, 68 observations in total, were used to estimate the supply model. The Box-Cox flexible functional form produces the following results:

$$(4) \quad Q^*_{us,t} = \underset{(1.31)}{0.06} + \underset{(3.30)}{2.84}P^*_{us,t} - \underset{(-3.01)}{2.72}P^*_{row,t} + \underset{(7.26)}{0.95}S^*_t + \underset{(5.50)}{0.402}Q^*_{us,t-1}$$

where numbers in parentheses are t values, and an asterisk means the variable is transformed by a power of 0.31.

The above results were obtained after correcting for the first-order autocorrelation with a rho value of 0.34 whose t value is 2.9. The R^2 and adjusted R^2 are 0.93 and 0.92, respectively. T statistics indicate that all of the independent variables do affect the supply of cultured Atlantic salmon from Norway to the United States. 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 2.56, -2.34, and 0.87, respectively. When the U.S. price increases (decreases) by 1 percent, the U.S. imports increase (decrease) by 2.56 percent in the short run, all else being equal. If the rest of the world bids up its price by 1 percent, in the short run it will receive 2.34 percent more cultured salmon from Norway. When the Norwegian supply of cultured Atlantic salmon is increased by 1 percent, the United States will increase its imports by 0.87 percent. In the long run, the elasticities of P_{us}, P_{row}, and S are 4.26, -3.90, and 1.35, 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 imports of Pacific salmon from the United States and Canada are in frozen form. Therefore, end uses of Atlantic salmon and Pacific salmon can be different. Hence the market relationship for cultured Atlantic salmon and chinook in France may differ from that in the United States. This issue can be investigated using either of the two econometric models as discussed below.

The demand model estimated previously for the United States is also applicable to the French market. In other words, it can be hypothesized that the French demand for cultured Atlantic salmon is affected by the prices of cultured Atlantic salmon and chinook, by French income, by previous consumption, and by seasonal dummy variables. The second model uses the market share approach, in which it is hypothesized that the share of chinook in the French Atlantic and chinook combined market is affected by the price ratio between chinook and Atlantic salmon and the previous market share. Because the market relationship for Atlantic and Pacific salmon is the focus of the analysis and because the market share model is less data demanding, the market share model is 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 used 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:

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

where SHARE denotes the share of Norwegian cultured Atlantic salmon in the French market. This is calculated by dividing total imports of Atlantic salmon by 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, whose coefficient should fall between 0 and 1, captures the partial adjustment effect. The share of chinook in the total market should become larger during the chinook season, so the variable D should have a negative coefficient.

French imports of chinook include shipments from both the United States and Canada. 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 United States nor Canada exported chinook to France for all 12 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. United States 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 chinook salmon 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:

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

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. The 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 counter-intuitive, but it has a low t statistic and hence is not statistically significant at reasonable levels 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 United States, 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 are 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 weak substitute for fresh chinook. The second model deals with the supply of Norwegian Atlantic salmon to the United States. It is found that the supply to the United States is affected by the prices paid by the United States and other importers of Norwegian Atlantic salmon. Total Norwegian production and previous supply to the United States 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 determine 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 United States and the rest of the world, respectively; S_{us} and S_{tot} are the supplies to the United States and the whole world, respectively; P_{us} and P_{row} are the prices paid for Norwegian Atlantic salmon by the United States and the rest of the world, respectively; P^*_{us} and P^*_{row} are prices of substitutes for Norwegian Atlantic salmon in the United States and the rest of the world, respectively; and X_{us} and X_{row} are other demand shifters (such as income, seasonality, etc.) in the United States and the rest of the 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 dynamic effect theoretically can be analyzed by including a time trend or the previous imports of Atlantic salmon, as specified in this study, 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. This latter effect has consumers switching from red meat to fresh and 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. The previous consumption was found to affect the current consumption, but this effect could be a combination of the market expansion effect induced by imports and changes in tastes and preferences.

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 the 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 an individual country's imports as weights in deriving composite income and price variables.

Second, monthly or quarterly data have 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, an additional problem may come from the fact that during the off-season (November to May) chinook ex vessel 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 non-troll-caught chinook, some discrepancies may develop here.

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