DRAFT

FUTURE PRICE OF FARMED ATLANTIC SALMON

July 31, 1989

Biing-Hwan Lin, Mark Herrmann, Tsae-Yun Lin, and Ron C. Mittelhammer

This paper is the result of work supported by the National Marine Fisheries Service, Department of Commerce, under award No. NA-88-ABH-0030. This is a submission for a selected paper for presentation at the American Agricultural Economics Association annual meeting at Baton Rouge, Louisiana, July 30 - August 2, 1989.

#6705

INTRODUCTION

The salmon fishery is the most valuable fishery in the west coast of the United States (U.S.) and Canada. In 1987, U.S. landings of wild Pacific salmon amounted to 562 million pounds worth 596 million dollars at the exvessel level. Past methods of production have been through the capture fisheries, in which the United States is the largest producer in the world. Recently, growing salmon in net-pens anchored in the ocean has become an increasingly important method of production. The species of salmon being farmed are mainly the highest-valued salmon species of Atlantic, chinook, and coho. Norway is the leader in salmon farming, having produced approximately 180 million pounds of Atlantic salmon in 1988; it is projected to produce 265, 309, and 331 million pounds in 1989, 1990, and 1991, respectively (Sakta Facts, 1988). World production of farmed Atlantic and Pacific salmon in 1990 is projected to nearly match the projected catches of chinook, coho, and sockeye salmon in the U.S. and Canada.

A recent concern of the salmon industry has been the substantial growth of pen-raised salmon from Norway, Scotland, Chile, Canada, and other countries. Fishermen are concerned to what extent the domestic and foreign markets will be affected by increased farm production. Existing and potential salmon farmers are concerned about the extent to which future revenues from salmon farming will be affected. The salmon industry as a whole hopes that the recent surges in the demand for fish will lead to increases in salmon demand which would offset supply increases so that the prices of salmon would remain high.

The U.S. and European Community (EC) are the main markets targetted by the Norwegian salmon farmers. The major expansion in demand for salmon has been in the U.S. resulting from consumers' dietary concerns. In Europe, Norway has replaced the

U.S. as the leading salmon supplier in some European countries such as France and Denmark.

Currently, salmon farming is only allowed in Washington and Maine, with Alaska issued another two-year moratorium on salmon farming in 1988. The start-up cost is high for salmon farming in the U.S. Heated and emotional political debates have resulted in an incredibly high cost for obtaining a farming license. Therefore, future price of farmed salmon is a much needed information for the salmon fishery.

The purpose of this study is to forecast the price of farmed Atlantic salmon in the U.S. and the EC for the period of 1989 through 1992. A dynamic simultaneous equation model is constructed to examine the factors affecting the supply and demand for farmed Norwegian Atlantic salmon in the U.S. and EC. Then, time series (Box-Jenkins) analysis is conducted to forecast future values of some of the exogenous variables of the econometric model. The econometric and time series models are then combined via dynamic simulation to generate future supply and price of Norwegian Atlantic salmon in the U.S. and EC. Sensitivity analysis is also conducted to examine the effects of different Norwegian production on future supply and prices.

THE ECONOMETRIC MODEL

The econometric model contains three behavior equations (U.S. demand, EC's demand, and supply to the U.S.) and four identities as specified below:

(1) $$Q_{usd} = f(P_{us}, PS_{us}, Y_{us}, D_i, Q_{usd,t-12})$$

(2) $$Q_{ecd} = g(P_{ec}, PS_{ec}, Y_{ec}, D_i, Q_{ecd,t-12})$$

(3) $$Q_{uss} = h(NP_{us}, NP_{ec}, STOT, \Sigma_{j=1,3} W^j Q_{uss,t-j})$$

(4) $Q_{usd} = Q_{uss}$

(5) $Q_{usd} + Q_{ecd} = STOT$

(6) $NP_{us} = P_{us} * ER_{us} * WPI_{us}$

(7) $NP_{ec} = P_{ec} * ER_{ec} * PPI_{ec}$

where Q_{usd} and Q_{ecd} are the demand for Norwegian Atlantic salmon in the U.S. and EC, respectively; Q_{uss} is the supply of Norwegian Atlantic salmon to the U.S.; P_{us} and NP_{us} are the U.S. prices of Norwegian Atlantic salmon in U.S. dollars and Norwegian kroners, respectively; P_{ec} and NP_{ec} are the prices of Norwegian Atlantic salmon in the EC measured in the European Unit of Account (ECU) and kroners, respectively; PS_{us} is the exvessel price of chinook salmon in the U.S.; PS_{ec} is the FOB (free-on-board) price of chinook, sockeye, and coho salmon exported from the U.S. and Canada to the EC; Y_{us} and Y_{ec} are income variables for the U.S. and EC, respectively; D_i represents a monthly indicator variable which is equal to one for the i^{th} month and zero for other months; $\Sigma_{j=1,3}W^jQ_{uss,t-j}$ is a three-month geometrically declining weighted average of past quantities with $\Sigma_{j=1,3}W^j = 1$; STOT is the total Norwegian exports to the U.S. and EC; ER_{us} and ER_{ec} are the number of kroners per U.S. dollar and ECU, respectively; and WPI_{us} and PPI_{ec} are the wholesale and producer price indexes in the U.S. and EC, respectively. All moneta... variables are expressed in real terms in equations (1) and (2) and in nominal terms in equation (3).

The justification for the model specification and data sources are discussed in Herrmann and Lin (1988) and Lin et al. (1989), they are not repeated here for the interest of brevity. However, empirical results are briefly summarized below.

Empirical Results

The econometric model, equations (1)-(3), are estimated by using the two-stage least squares method for the sample period from January 1983 through December 1988. It should be mentioned that the 1988 figures for PS_{ec} are missing and substituted by using the results of time series analysis. Therefore, the econometric results should be regarded as preliminary. The Cochrane-Orcutt iterative technique is used to correct the first-order autocorrelation problem which is present in equations (2) and (3). The empirical results of the double-log functional form are summarized below, with the absolute values of t statistics in parentheses.

(8)

$$\ln Q_{usd} = -\underset{(6.40)}{2.31}\ln P_{us} + \underset{(1.79)}{0.31}\ln PS_{us} + \underset{(3.73)}{3.01}\ln Y_{us} + \underset{(3.09)}{0.24}\ln Q_{usd,t-12}$$

$$-\underset{(2.24)}{5.10} - \underset{(1.05)}{0.18D2} - \underset{(0.29)}{0.05D3} - \underset{(0.44)}{0.07D4} - \underset{(0.25)}{0.04D5} - \underset{(0.89)}{0.14D6}$$

$$-\underset{(2.03)}{0.33D7} - \underset{(1.70)}{0.29D8} - \underset{(1.50)}{0.29D9} - \underset{(1.26)}{0.24D10} + \underset{(0.76)}{0.15D11} + \underset{(0.85)}{0.15D12}$$

R2 = 0.864, Adj. R2 = 0.828, D-W = 1.63

(9)

$$\ln Q_{ecd} = -\underset{(3.80)}{2.42}\ln P_{ec} + \underset{(1.54)}{0.54}\ln PS_{ec} + \underset{(1.46)}{1.55}\ln Y_{ec} + \underset{(1.69)}{0.32}\ln Q_{ecd,t-12}$$

$$+\underset{(0.31)}{0.72} + \underset{(0.15)}{0.01D2} + \underset{(1.13)}{0.13D3} + \underset{(1.19)}{0.15D4} + \underset{(1.81)}{0.27D5} + \underset{(2.44)}{0.39D6}$$

$$+\underset{(1.81)}{0.28D7} + \underset{(1.32)}{0.19D8} + \underset{(2.37)}{0.34D9} + \underset{(2.82)}{0.39D10} + \underset{(3.32)}{0.47D11} + \underset{(3.17)}{0.49D12}$$

R2 = 0.919, Adj. R2 = 0.900, D-W = 2.02, Rho = 0.735

(10)

$$\ln Q_{uss} = \underset{(0.15)}{0.54} + \underset{(2.60)}{3.75}\ln NP_{us} - \underset{(3.16)}{4.49}\ln NP_{ec} + \underset{(6.46)}{0.71}\ln STOT + \underset{(2.69)}{0.31}\ln \Sigma_{j=1,3} W^{j} Q_{uss,t-j}$$

R^2= 0.860, Adj. R^2 = 0.852, Rho = 0.664

All estimated coefficients have signs consistent with a priori theoretical expectations and are significant at a 5% probability level with the exception of monthly dummy variables, the EC income and the substitute prices in the EC. Judging from t statistics, R^2, and other summary statistics (such as validation statistics developed by Theil), the model appears to have a good fit.

Because of the double log functional form, the estimated coefficients can be interpreted as short-run elasticities. The long-run elasticities can be calculated by using the coefficients of the lagged consumption variables. These elasticities suggest that farmed Atlantic salmon is a luxury good and the demand is fairly price elastic in the U.S. and EC. Pacific salmon is found to be a substitute but not a good substitute for farmed Atlantic salmon. Empirical results also suggest that the demand for farmed Atlantic salmon exhibits a seasonality in the U.S. and EC. In the U.S., the weakest demand occurs during the strongest part of the Pacific salmon fishing season from June to October. A particularly heavy demand is exhibited in the EC during November and December when the demand for smoked salmon in Europe is very intense over the holiday season.

TIME SERIES MODELS

There are nine variables (PS_{us}, PS_{ec}, Y_{us}, Y_{ec}, STOT, ER_{us}, ER_{ec}, WPI_{us}, and WPI_{ec}) considered to be exogenous to the model and their future values need to be generated for forecasting the future supply and price of Norwegian Atlantic salmon in the U.S. and EC. Time series analysis was conducted to forecast future values of all exogenous variables except STOT, ER_{us}, and ER_{ec}.

Future production of Norwegian farmed Atlantic salmon for the period from 1989 though 1991 was discussed in the introduction section. Future production for 1992 is assumed to be 22 million pounds above the 1991 projected production. Because the projected production for 1989 is 33.3% above the actual production for 1988, a sensitivity analysis is performed in which future production is assumed to be 10% below the projection. Exchange rates are volatile and difficult to forecast, so ER_{us} is assumed to be equal to 6.53 and ER_{ec} equal to 7.70, the level occurred in December 1988.

Using monthly data from January 1982 through December 1987, six time series models were estimated. The results are summarized below, with the absolute values of t statistics shown in parentheses and measures of goodness of fit summarized in Table III.

(11) $\nabla \ln Y_{us} = \underset{(7.39)}{0.0063} + (1 - \underset{(2.60)}{0.299}B)\,\epsilon_1$

(12) $\nabla Y_{ec} = \underset{(4.98)}{3.25} + (1 - \underset{(8.91)}{0.763}B + \underset{(2.39)}{0.206}B^4)\,\epsilon_2$

(13) $(1 - \underset{(5.54)}{0.719}B)\,\nabla_{12} PS_{us} = (1 - \underset{(2.23)}{0.413}B - \underset{(2.79)}{0.587}B^{12})\,\epsilon_3$

(14) $(1 + \underset{(2.08)}{0.24268}B)\,\nabla WPI_{us} = \underset{(2.13)}{0.36325} + \epsilon_4$

(15) $(1 - \underset{(8.49)}{0.8874}B)\,\nabla \ln WPI_{ec} = \underset{(2.36)}{0.004} + (1 - \underset{(3.95)}{0.678}B)\,\epsilon_5$

(16) $\nabla PS_{ec} = (1 - \underset{(2.57)}{0.294}B)\,\epsilon_6$

where ∇ is the first-order difference operator and $\nabla_i Y_t = Y_t - Y_{ti}$; B is the backward shift operator and $B^i Y_t = Y_{t-i}$; and ϵ_i is the error term.

FUTURE SUPPLY AND PRICE

Given the forecasted values of all exogenous variables, the estimated econometric equations and identities can be solved to generate the future supply and price of Norwegian Atlantic salmon in the U.S. and EC. For the interest of brevity, future supply and prices are aggregated from a monthly basis into yearly basis and are shown in Tables 1-2. It should be pointed out that the estimated economic structures (econometric and time series) are assumed to remain unchanged during the forecasting period.

It is important to note that the forecasted values presented in Tables 1-2 are conditional on the predicted values of exogenous values discussed in the previous section. The time series models predict that U.S. and EC income figures will follow an upward trend during the prediction period. The exvessel price of chinook in the U.S. is predicted to repeat a seasonal pattern, and the FOB price of chinook, sockeye, and coho is set at a constant. Exchange rates are assumed to be constant, but in reality they will vary. One of the main advantages of the integrated econometric and time series approach is that the econometric model can be used to generate future supplies and prices under alternative predictions of the exogenous variables. This advantage is utilized in the sensitivity analysis in which Norwegian production is assumed to be 10 percent below the predictions given by the Norwegian source. It should be mentioned that sensitivity analysis can also be conducted to examine the effects of exchange rates, income, inflation, prices of substitutes on the supply and price of Norwegian farmed salmon in the U.S. and EC.

U.S. Market

The price of farmed Atlantic salmon has undergone a great deal of fluctuation from 1982 to 1987, as shown in Table 1. In the U.S., FOB prices declined from $3.21 per pound in 1982 to $2.87 in 1984, bottomed out at $2.80 in 1986, skyrocketed to $3.50 in 1987 caused by great reduction in supply due to disease problems, remained fairly high in early 1988 and then started decling in later 1988. The supply of Norwegian farmed salmon rose steadily from 1.5 million pounds in 1982 to 20.6 million pounds in 1986, dropped to 17.9 million pounds in 1987 due to disease problems, then rose again to 21.4 million pounds in 1988.

As Norwegian production is projected to increase from approximately 180 million pounds in 1988 to 265 million pounds in 1989, supply to the U.S. in 1989 is predicted to be nearly double the 1988 figure causing price to decline to the 1984 level which is 19 percent below the 1988 price. As growth in Norwegian production is predicted to slow down, increases in supply to the U.S. are predicted to slow down as well but FOB prices are predicted to follow an upward trend starting with $3.04 per pound in 1990 and reaching $3.35 in 1992. The predicted 1991-1992 prices are about 4.3-9.3% below the 1987-1988 prices.

When the projected production of Norwegian farmed supply is assumed to be smaller by 10 percent, supply to the U.S. is predicted to be 35, 45, 52, and 60 million pounds for 1989, 1990, 1991, and 1992, respectively. Consequently, future prices rise starting with $3.03 per pound in 1989 and reaching $3.40 in 1992.

EC Market

FOB prices and supply to the E.C. behaved somewhat differently compared to the U.S. market, possibly caused by the appreciation of the ECU in relation to the U.S. dollar. U.S. dollars appreciated from $0.977 per ECU in 1982 to $0.777 in 1985 and then depreciated to $0.990 in 1986 and $1.183 in 1988. Growth in the Norwegian supply to the EC was much smaller than to the U.S. during the period when the U.S. dollar appreciated against the ECU. Consequently, the FOB price of Norwegian salmon shipped to the EC went up from about 3.00 ECUs per pound to 3.57 ECUs in 1985.

When the ECU appreciated by almost 28% in 1986, supply to the EC rose from 33 million pounds to 57 million pounds causing price to plummet from $3.57 ECUs per pound to only 2.52 ECUs in 1986. Continuing surging in the value of ECU kept the FOB price in 1987 to remain relatively low even though Norwegian total production was hit by disease problems. Continuous strength in the value of ECU coupled with recovered Norwegian production in 1987 caused the FOB price to drop from 2.85 ECUs per pound in 1987 to 2.67 ECUs in 1988 as traded volume increased from 68 million pounds in 1987 to 108 million pounds in 1988.

If, indeed, Norwegian production increases by 33.3% in 1989, Norwegian exports to the EC are predicted to rise to 157 million pounds resulting a lower price of 2.34 ECUs per pound. After 1989, prices in the EC are predicted to follow an upward trend starting with 2.43 ECUs in 1990 and reaching 2.58 ECUs in 1992, the same movement predicted for the U.S. market.

If Norwegian production is 10% below the projected figures for the period 1989-1992, exports to the EC are predicted to be 145, 166, 174, and 181 million pounds for 1989 through 1992, respectively. Prices are predicted to be 2.43, 2.49, 2.58, and 2.65 ECUs for the same period.

SUMMARY AND FUTURE RESEARCH

Future prices of farmed Atlantic salmon is much needed information for decision making by the salmon industry. Because future demand for and supply of farmed salmon are expected to increase simultaneously, the future price movement of farmed salmon is uncertain. In this paper, econometric and time series models are integrated to generate future prices and supply of Norwegian Atlantic salmon in the U.S. and EC.

Many salmon farmers in the U.S. and elsewhere believe that the rate of increase in the demand for salmon will keep pace with the phenomenal increase in supply so that the price will remain high in the near future. Indeed, the econometric results suggest that the demand for farmed salmon is very price elastic so that the market appears to be sizeable. However, it is predicted that the market demand, even under continuous economic growth in the U.S. and the EC, will not match the phenomenal growth in supply during the 1989-1992 period without some price decrease.

The high income elasticity generated by the econmetric model suggests that the price of farmed Atlantic salmon is very sensitive to the world economy. Salmon farmers should be aware of the fact that the degree of price fluctuation for farmed salmon will be greater than the degree of the swing in the economy. Therefore, an economic recession worldwide would have significant adverse effects on price.

The econometric model also suggests that farmed Atlantic salmon and high-valued Pacific salmon are substitutes in the U.S. and the EC. Because farmed salmon is usually marketed in fresh/chilled form, it commands a higher price than captured salmon. If the price of farmed salmon declines due to the faster increase in supply relative to demand, the degree of substitutability between farmed and captured salmon will intensify. This substitution may also intensify as more of the farmed salmon is targetted during the Pacific salmon fishing season when Pacific salmon is marketed fresh in the United States. Currently most farmed salmon is targetted during the winter and spring in the U.S., when Pacific salmon is sold frozen, as evident from the econometric results. Therefore, improved processing and marketing methods are needed by the Pacific salmon fishery. This appears to be particularly important in the European market, the second most important U.S. export market for captured salmon, because Norway has a locational advantage in supplying this market.

One of the main advantages in using econometric models for forecasting involves the possibility of conducting sensitivity analysis. In this paper, sensitivity analysis is conducted to examine the effects of Norwegian production on the prices and supply in the U.S. and EC. Sensitivity analysis can also be conducted for examining the effects of exchange rates, income, and inflation. However, it is well known that econometric and time series models can be useful tools for short-term rather than long-term forecasting, especially in the case of changing economic structures. Since the market for farmed Atlantic salmon is fairly new and future supply is increasing rapidly, univariate time series analysis alone may not be a reliable tool for even short-term forecasting. In addition, a continuous update of the econometric model is crucial in improving its usefulness in forecasting. Our modelling experience clearly indicate that model specification in terms of variable and functional form selection requires special attention when the sample period is enlarged. There are additional work needed for improving the forecasting accuracy of the approach adopted in this study. They are briefly discussed here.

First, the price of Pacific salmon is treated as an exogenous variable in the econometric model. Endognization of this variable will be useful in not only improving the forecasting ability of the approach by also studying the impact of salmon farming on capture fishery.

Second, Norway is likely to diversify its export destinations for farmed salmon when its production expands. For example, Japan has increased its imports of Norwegian

Atlantic salmon in recent years. Therefore, attempts should be made to expand the econometric model when sufficient data is available.

Finally, production of farmed salmon other than the Atlantic in countries other than Norway is expected to expand rapidly in the near future. The substitutional relationship between different species of farmed salmon from different origins needs to be included in econometric modelling. However, the current data base may not be sufficient to support such an attempt. For this reason, our price forecasts reported in this paper should be regarded as upper bounds if a large amount of other farmed salmon is placed on the market in the near future.

Table 1. Supply of Norwegain Farmed Atlantic Salmon: 1982-1992

Year	U.S.	EC
	.....1,000 pounds.....	
1982	1,501	16,125
1983	5,265	24,731
1984	10,404	28,547
1985	14,565	33,375
1986	20,597	57,002
1987	17,864	67,886
1988	21,351	107,732
1989	41,351	157,240
1990	50,070	181,413
1991	57,276	190,744
1992	65,894	198,660

Table 2. FOB Prices of Norwegian Farmed Atlantic Salmon: 1982-1992

Year	U.S. Dollars/lb	EC ECU/lb
1982	3.21	3.02
1983	3.00	3.19
1984	2.87	3.30
1985	3.06	3.57
1986	2.80	2.52
1987	3.50	2.85
1988	3.54	2.67
1989	2.86	2.34
1990	3.04	2.43
1991	3.21	2.51
1992	3.35	2.58

REFERENCES

Herrmann M. and B.H. Lin. "The Demand and Supply of Norwegian Atlantic Salmon in the United States and the European Community." Canadian J. of Agri. Econ. 36(1988):459-471.

Lin, B.H., M. Herrmann, T.Y. Lin, and R.C. Mittelhammer. "Forecasting the Price of Farmed Atlantic Salmon: An Integrated Econometric and Time Series Approach." Agribusiness: An International Journal. (Forthcoming, 1989).

Sakta Facts. Personal communication with Dr. Kjell Salvanes. May 16, 1989.

Theil, H. Applied Economic Forecasting. Chicago: Rand McNally and Co. Amsterdam: North Holland Publishing Co. 1966.