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Price Uncertainty, Expectations Formation and Fishers' Location Choices

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Abstract *This paper deals with the effects of uncertain output prices upon fishers' location choices. It employs ARIMA models to construct the price forecasts used by fishers in a model which generates expected profits for three fishing locations in the British Columbia salmon fishery. A random utility model of fishing location choice is then estimated using two different sets of regressors. The first is expected seasonal profit and its variability. The second is expected wealth and its variability, where expected wealth is taken to be the sum of the known pre-season wealth and the expected profitability of a given fishing location. Results show that expected profitability is a significant determinant of fishing location choice but that expected wealth plays an even bigger role. This suggests that there is a type of wealth or stock effect present in decisions made by fishers. The results also provide evidence that the variability of profits or wealth is generally a less significant component in regard to fishing location choice. In fact, some fishers thrive on greater variability, thereby providing some evidence of the risk loving behaviour typically attributed to fishers. This is not the case, however, for all fishers since some are found to be risk-neutral and even risk-averse. Given the finding that fishers do respond to economic incentives, one policy implication concerns the ability of fisheries managers to alter the dispersion of fishers over fishing locations via the adjustment of the economic incentives by means of differential royalty taxes. A second policy implication results from the finding of risk-loving behaviour. This calls into question models that assume risk-averse behaviour and predict a dominance of crop-sharing contracts over wage contracts.*

Keywords Uncertainty, location choice, random utility, risk preferences.

Introduction

Fishing is an inherently uncertain activity. This research is an examination of the role of uncertainty in the determination of fishers' decisions regarding location choice. This paper concentrates upon only one aspect of that uncertainty, namely, the uncertainty surrounding the prices fishers may expect to receive for their catches. *Ex ante,* fishers do not know the prices that they will obtain for their catches, but, nevertheless, they must make decisions early in the season about where to fish since it is costly to change locations within a season. This paper

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assumes that two different sets of factors may influence the fishing location choice. The first set of factors comprises expected seasonal profit and its variability. The second set of factors comprises expected wealth and its variability. In this paper, expected wealth is taken to be the sum of the known pre-season wealth and the expected profitability of a region which is largely determined by the expected price of the fish caught there. Thus, this second set of factors acknowledges the potential for a wealth or stock effect to influence current decisions.

In spite of the prevalence of uncertainty in fishing, little research has been done to examine its impact upon the decision-making of individual fishers, although the literature contains some work that looks at the effects of uncertainty upon the behaviour of the fishery as a whole in terms of aggregate effort decisions (Reed, 1979; Pindyck, 1984). However, two key articles that concentrate upon the behaviour of individual fishers in the presence of uncertainty are relevant to the research in this paper. Andersen (1982) and Bockstael and Opaluch (1983). The former looks at single location fishing decisions under uncertainty where the fisher is concerned with expected profit maximization. The latter examines the role of expected utility maximization in a random utility model of fishing location choice.

This paper draws in particular upon the work of Bockstael and Opaluch (1983). They estimate a logit model of fishing location choice using expected wealth and its variability as determinants. Because of data limitations they are unable to generate observations of expected profit and its variability for individual fishers. Their data are limited to industry average values for different sizes of fishing operations, hence, they must assume that all fishers of a particular size class are identical. Expected net revenues for a variety of vessel size classes in alternative locations are calculated using an adaptive expectations type process (a Koyck distributed lag on the average values for actual returns over the five previous years). Average wealth for different size classes is predicted from an equation solved by a maximum likelihood search procedure. In their equation wealth is defined as a constant and some proportion of the average market value of fishing vessels in different size classes.

One limitation of their approach is that fishers are assumed to have knowledge about average returns by location of different vessel classes. First, it is unlikely that fishers will reveal their returns to their competitors, although, they are more than willing to boast about good prices for their catches. Second, average returns are useful only to the average fisher and may provide little relevant information to better or worse fishers. A second limitation of the Bockstael and Opaluch paper is that, given the data limitations imposed by using average returns, they need to incorporate wealth to get sufficient variation in observations to estimate the model. Thus, they are unable to separate out the wealth or stock effect upon fishing location choices.

Using a three stage procedure this paper seeks to extend the empirical approach adopted by Bockstael and Opaluch and to address some issues raised in their modelling. In the first stage, the paper assumes that fishers can form expectations about the future values of uncertain variables from the observed past behaviour of these variables. The variables in question are the prices received for the fisher's catches of different types of fish. The paper assumes that the expectations formation process used by the fisher to obtain forecasts of fish catch prices is consistent with the application of an ARIMA model.

The second stage of the paper takes the ARIMA price forecasts from stage one and uses them as instrumental variable regressors in the estimation of micro-level seasonal expected profit functions for each of three fishing locations in the British Columbia salmon fishery. Output from this stage includes location-specific expected profits and their variances for each fisher in the sample.

In the third and final stage of the analysis, the paper pulls together the results obtained from the first two stages and estimates a discrete choice or random utility model of fishing location choice. Two different approaches are taken for the modelling of the key components. Model 1 assumes that fishers care only about expected seasonal profit and its variability when choosing a fishing location. Model 2 takes an alternative view that fishers base their location choices upon expected wealth and its variability, where expected wealth includes not only the expected profit to be earned from choosing a particular fishing location, but also the stock of known pre-season wealth.

The results are supportive of the approach. Both expected profit and expected wealth matter to fishers when choosing a fishing location, although, variability is not as important. Expected wealth appears to be a more significant determinant of fishing location choice and the wealth or stock effect that it incorporates can turn risk-averters into risk-lovers and vice versa.

The organization of the paper is as follows. In the next section, the stage three model is presented first since it explains what type of information is required from stages one and two. The third section discusses both the ARIMA model estimation and results and the expected profit estimation and results. The fourth section presents the results of the logit model of fishing location choice and the last section gives conclusions and discusses some policy implications.

Modelling the Fisher's Location Choice Decision

Given the uncertainty faced by fishers, what can be said about the motivating factors that contribute to the actual choices observed? Andersen (1982) adapts Sandmo's model (1971) of a competitive firm operating under price uncertainty to the case of a fishing firm. He examines behaviour in a single fishery without locational choice decisions. He assumes that fishers maximize the expected utility of profit and that they exhibit decreasing absolute risk aversion. He shows that the possibility of an increase in the variability of profits encourages fishers to reduce their fishing effort. From this, one can conclude that higher expected profits and lower variability of those profits will encourage more fishing. Bockstael and Opaluch (1983) explicitly examine the role of expected utility maximization in a random utility model of fishing location choice and find that fishers respond to economic incentives in the way one would expect *a priori*. Namely, fishers respond to locations with a higher expected gain and a lower variability of gain.

This paper draws upon the previous work to develop a model of fishing location choice under uncertainty. The model assumes that the jth fisher derives utility U_{ji} from fishing in the ith location where U_{ji} depends upon a vector of attributes $(\overrightarrow{X}_{ji})$ of fishing location i as viewed by fisher j.

$$U_{ji} = \tilde{U}(\overrightarrow{X}_{ji}) + \epsilon_{ji} \tag{1}$$

The error term ϵ_{ji} represents characteristics of the location which are unobservable to the researcher, for example, the weather.[1] The jth fisher is assumed to choose the fishing location that maximizes his utility. The probability of his choosing location i over an alternative location k is determined by the following:

$$\text{Prob}_{ji} = \text{Prob}\{\epsilon_{jk} < \bar{U}(\vec{X}_{ji}) - \bar{U}(\vec{X}_{jk}) + \epsilon_{ji}\} \tag{2}$$

If the researcher assumes that the ϵ's are distributed as identical and independent log Weibulls, this implies that the problem takes on a multinominal logit formulation (Maddala, 1983).[2]

The multinomial logit model provides the following probability that fisher j will choose location i. Note that in the denominator, k = i.

$$\text{Prob}_{ji} = \frac{e^{\bar{U}(\vec{X}_{ji})}}{\sum_{k=1}^{K} e^{\bar{U}(\vec{X}_{jk})}} \tag{3}$$

Therefore, the likelihood function for the model is given by equation (4).

$$L = \prod_{j=1}^{J} \prod_{k=1}^{K} \left[\frac{e^{\bar{U}(\vec{X}_{ji})}}{\sum_{k=1}^{K} e^{\bar{U}(\vec{X}_{jk})}} \right]^{y_{ji}} \tag{4}$$

In this equation y_{ji} takes a value either of one (if fisher j chooses fishing location i) or of zero (if he chooses an alternative location).[3] Once a specific form is chosen for the utility function, maximum likelihood estimation of equation (4) yields estimates of the parameters of the utility function that are consistent and asymptotically efficient.

For the purposes of empirical implementation, this paper adopts the frequently used logarithmic utility function. This is a simple well-behaved function that exhibits the properties of a positive first derivative and negative second derivative. Together, the signs on these derivatives imply that fishers are risk-averse and

[1] *A priori* weather is unobservable to the fisher, as well.

[2] The log Weibull type of error distribution has the useful property that the cumulative density of the difference between two random variables (each following the log Weibull distribution) is given by a logistic function. Hence, the probability of choosing one option (location) can be expressed as a logistic function whose bounds are zero and one. This property gives a well defined likelihood function. If one does not assume that the distribution is log Weibull, then the multinomial logit model does not result.

[3] The multinomial logit model assumes that the property of independence of irrelevant alternatives applies. This says that the relative probability of choosing any pair of alternatives is constant when new choices are added to the set of options.

have decreasing absolute risk aversion. The paper looks at two alternative specifications for the components that determine utility, i.e., the components of the vector of regressors ($\overrightarrow{X}_{ij}$) identified in equation (4). For Model 1, utility is assumed to be a function solely of the seasonal profit from the current year's fishing. For Model 2, utility is assumed to be a function of a fisher's wealth, where wealth is the sum of the known pre-season wealth and the fisher's profit from a given fishing location. (The methods used to generate both profit and pre-season wealth are described in the next section.)

When faced with uncertain prices and, therefore, an uncertain profit from a specific location, maximization of expected utility will motivate the fisher's location choice decision.[4] For the logarithmic utility function chosen above, an expression for the expected utility of the jth fisher is obtained by taking a Taylor's series expansion, as in equation (5).[5] This equation assumes that only the first two moments of the utility function matter.

$$E[U(W_j)] \simeq \ln[W_j + E(\pi_j)] - .5 \frac{Var(\pi_j)}{[W_j + E(\pi_j)]^2} \tag{5}$$

The first term on the right hand side of equation (5) is the first regressor (*i.e.*, $X_{1\ ij}$) in the vector $\overrightarrow{X}_{ij}$ of variables shown in equations (1)–(4). This first regressor represents either the expected profit or wealth resulting from the choice of a specific fishing location. The second term is the second regressor ($X_{2\ ij}$). It represents the variability of either expected profit or wealth. *A priori* one expects the first regressor to have a positive parameter value and the second to have a negative parameter value.

In order to estimate the maximum likelihood model obtained when the expected utility function from equation (5) is submitted into equation (4), the researcher needs to have values for the two regressors identified above. It is possible to generate this type of information for the British Columbia commercial salmon fishery because the necessary micro-level data are available. The next section describes how this research generated the required data, namely, fisher-specific values for a) known pre-season wealth, b) expected profits in each of the three fishing locations, and c) the variability of those profits or wealth.

Modelling and Estimating Expected Profits for Different Locations

There are two stages to the modelling of expected profits from different fishing locations. The first is the specification and estimation of a process by which fishers form expectations about the future prices for their catches. The second is to use these expected prices as instrumental variable regressors in a model that predicts expected profits in the alternative fishing locations.

[4] Each fisher is assumed to operate as a Nash competitor, taking the actions of fellow fishers as given. The large number of fishers in the case study (over 4500) supports this assumption.

[5] Equation (5) includes the possibility of both types of specifications for the treatment of pre-season wealth. In the case of Model 1 (profits matter only), pre-season wealth is given a value of zero. In the case of Model 2 (wealth or stock effect), pre-season wealth is given a positive value, constant across all possible fishing locations.

Stage One: Arima Price Forecasts

When forming expectations about the current period's expected price, it is reasonable to assume that fishers try to use all available information. This paper assumes that fishers look not only at past periods' prices as indicators of the current expected price, but that fishers are rational in the sense that they use all available information to help form price expectations. Thus, fishers allow for adjustments according to random errors in their previous predictions. A reasonable approach to modelling the formation of price expectations in this fishery is to assume that fishers form rational expectations. Nerlove *et al.* (1979) have shown that ARIMA (Box and Jenkins, 1976) models such as the one shown in equation (6) produce forecasts that have a number of the properties of Muth's (1961) rational expectations model.

$$P*_t = \phi_1 P*_{t-1} + \phi_2 P*_{t-2} + \ldots + \phi_n P*_{t-n} + \epsilon_t + \theta_1 \epsilon_{t-1} + \theta_2 \epsilon_{t-2} + \ldots + \theta_m \epsilon_{t-m} \tag{6}$$

This model assumes that the current value of the price variable in question, $P*_t$, depends upon past values of the price ($P*_{t-1}$, $P*_{t-2}$, . . . , $P*_{t-n}$), as well as the current random error (ϵ_t) and past random errors, ϵ_{t-1}, ϵ_{t-2}, . . . , ϵ_{t-m}.

The coefficients to be estimated are ϕ_1, ϕ_2, . . . , ϕ_n and θ_1, θ_2, . . . , θ_m. The ϕ coefficients correspond to the autoregressive components, while the θ coefficients correspond to the moving average (random errors) components. Typically, the ϕ coefficients decline in value the longer the lag thereby indicating that the influence of earlier observations of prices declines quickly. The number of significant θ coefficients indicates how many previous year's random disturbances are averaged into the current value of the variable in question. In order to estimate an equation like (6) the time series of prices must be stationary (that is, the mean and variance of the series are the same over the length of the series). Frequently, economic time series do not exhibit stationarity. Taking first or second differences of the original variable most often yields the desired stationarity property. Prior to estimation each series is checked to see if it satisfies the stationarity property. This is discussed further following a brief description of the data used.

The case study of this paper is the British Columbia salmon fishery. There are five sub-species of salmon caught by four different vessel types (seine, troll, gillnet-troll, and gillnet) in British Columbia. These vessels operate in one of three main locations (North Coast, West Coast, and Georgia and Juan de Fuca Straits). The season extends from March to November, although it is shorter for some species. Given that there are a large number of vessels (around 4500) that participate annually in this fishery, it is reasonable to assume that each fisher takes catch prices as given but uncertain at the beginning of the fishing season.

There are (at least) four different explanations for variability in expected prices for caught fish. First, certain sub-species (*e.g.*, chinook and coho) obtain higher prices because they have a more desirable flesh texture than the other three sub-species (sockeye, chum, and pink), although the premia vary by species and over time. Second, the time of the year in which the fish are caught can contribute to price variation. Early catches often command higher prices. Third, prices vary by vessel type even for the same sub-species. Vessels using nets (seine and gillnet type vessels, as well as the gillnet-troll vessel) get lower prices than vessels using hooks and lines (troll vessel types) because nets can leave unsightly burn marks on the skin. In addition to these explanations of price variation, prices vary by fishing location even after taking account of the other causes. This price variation may be attributed to transportation costs of the purchasers. However, insofar as the fisher is concerned, location matters in terms of obtaining different prices for the same catch. Fishers are able to form expectations of these prices from information easily obtained from the Department of Fisheries and Oceans which monitors and makes public catch price data over the season.

In order to generate expected prices, the first stage of the project estimates a series of ARIMA models for different constellations of species, location and vessel types using seasonal time series data from the salmon fishery. Once the models are estimated, the estimated coefficients are used with previous period prices and disturbance values to provide forecast prices for the 1982 fishing season.[6]

Organization of the data begins with 16 years of panel type price data (1967–1982) from a random sample of vessels—so called "Catch Statistics."[7] Each time a vessel lands a catch, the owner must submit to the government information on a set of statistics that include for each species the catch quantities, value, fishing region, and date of fishing trip. I use a random number generator to obtain panel data on a sample of some 800 vessels that have operated in each of the years from 1967–1981. This represents from 10–15% of the total number of vessels in any time period. I then separate these catch statistics data according to the types of vessels that operate in the salmon fishery. For each vessel type, each year contains from 8000–12000 records.

Within each vessel type I further subdivide according to location, salmon sub-species and period. The number of periods within a year is either 4, 5, or 6, according to the sub-species, but the number of periods is the same for each year. Using this raw data I calculate the mean values for the landed price of each salmon sub-species by fishing location for each period in the years 1967–1982. Since there are five salmon sub-species and three locations, this yields 15 different time series of prices for each vessel type. These data are then used as the basis for obtaining forecasted species-location-period-specific prices for each of the four vessel types through the ARIMA modelling process.[8] The 1982 data are not used in the estimation, rather, they are used to verify the models.

The three regions (North, West, and Georgia) follow from the geography of Coastal British Columbia. Mainland British Columbia is attached to the rest of

[6] The year 1982 is chosen because it corresponds to the year for which individual fisher survey data on fishing operations are available. These data make it possible to estimate micro-level models of profit-maximizing fishing behaviour which are then used to construct expected regional profits and their variance for each fisher.

[7] The vessels in the random sample time series data cannot be linked to the vessels in the survey data used to estimate the locational profit functions. So, although there may be some overlap between the vessels used in the two data sets, I am unable to discover its extent. It would have been preferable to have been able to link the two data sets, however, this proved impossible. This motivated the use of a random number generator method to choose which vessels's prices were to be included as the raw data in the ARIMA forecasting exercise.

[8] The time series data did not permit me to identify gillnet-troll vessels separately from either gillnet or troll type vessels. Hence, for the former vessels, I average the price forecasts for the gillnet and troll vessels. This assumes that gillnet-troll vessels spend half of their fishing time using gillnet equipment and the other half using troll equipment.

Canada. Vancouver Island lies about 45 kilometres to the west of the mainland. The North region is the area north of Vancouver Island extending all the way to Yukon and Alaska, West is the area to the west of Vancouver Island, and Georgia is the area between the Mainland and Vancouver Island, including Juan de Fuca Strait which is situated south of Vancouver Island and north of Washington State.

Prior to estimation the price series are examined in two ways. First, each price series is plotted with respect to time. In addition, plots of the autocorrelation and partial autocorrelation functions are examined in order to make initial guesses about the nature of the time series process. For many of the price series examined time series plots indicate that much of the data has a very strong seasonal component. For these cases, a seasonal differencing procedure is used to remove this trend. In addition, many of the series require first differencing in order to satisfy the stationarity requirement. Second, a series of pairwise correlations are calculated between the 45 price series to determine the degree of interrelatedness. These results show that coho and chinook prices for the troll fleet have the highest correlations (between 0.77 and 0.89) across the three areas. However, correlations for the other species and vessel types are much lower, ranging between 0.011 and 0.740, with the majority falling in the range between 0.250 and 0.450.

Given the large number of ARIMA models estimated, results for each individual series are not reported here in detail, however, some general information pertaining to the series as a whole is provided, followed by detailed information on three price series.[9] In most cases, the estimated price series appear to have a one period autoregressive component, and, for some series, a two or three period seasonal autoregressive component. Approximately, one half of the series have a one period moving average component. Coefficients on the parameters are largely highly significantly different from zero. Box-Ljung statistics at 16 lags for the residuals of the estimated models are found to be statistically insignificant, indicating that the residuals are white noise, i.e., that all relevant information has been incorporated into the parameter estimates.

Three price series are chosen for presentation of a detailed analysis of estimation results. These series all pertain to prices received by the seine vessel type for the sockeye species. Thus, these three series show price expectations for the same vessel and species constellation for each of the three locations: North, West, and Georgia. Figures 1–3 plot the actual and predicted values for each of the three prices series. Table 1 shows the estimated coefficient values, t-statistics, and Box-Ljung statistics for each of the these three models. Each model is estimated using the maximum likelihood method on equation (6). Models with seasonal autoregressive components require nonlinear maximum likelihood.

For the North location, the estimated ARIMA model requires first order differencing, has two lagged price terms, no moving average terms, and one seasonally lagged price term. According to the naming conventions used in ARIMA modelling this combination is written as (2,1,0)(1,0,0). The first set of brackets pertains to the non-seasonal part of the price series. The first number indicates the number of lagged price terms, the second number shows the number of times the original price series has been differenced, and the third number indicates the

[9] Results not appearing in the paper are available from the author.

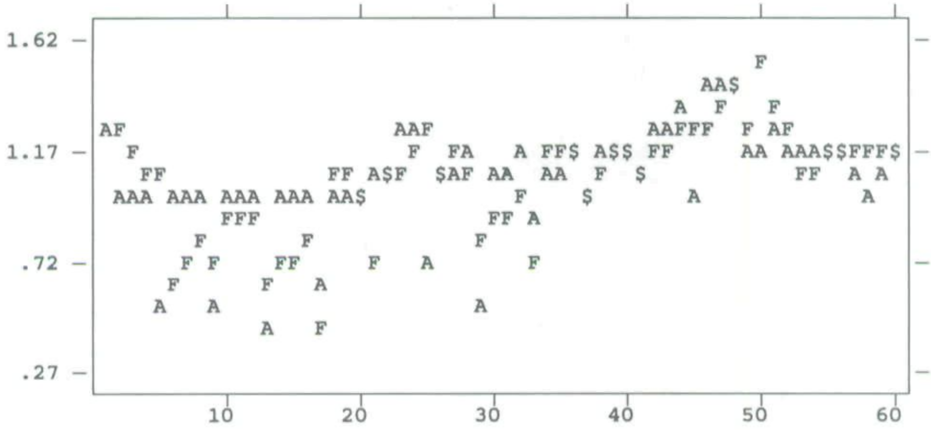

Figure 1. Plot of Actual and Forecast Prices for Sockeye Salmon. North Location—1968–1982, Seine Vessels.

Notes:
The following symbols are used:
A–Actual Price (Real 1981 Dollars)
F–Forecast Price
$–Where Forecast Price equals Actual Price

This price series has four periods in each year. Actual prices begin with period 1 in 1968 and continue to period 4 in 1982. Predictions begin with period 2 in 1968 (because of the autoregressive components and the first differencing of model) and continue to period 4 in 1982.

degree of the moving average process. The second set of brackets uses this same ordering system but refers to the seasonal aspect of the data. For the West location, the estimated model requires a first order differencing, has two lagged price terms, no moving average term, and a seasonal first order difference along with two seasonally lagged price terms. Finally, the salmon sockeye price series for the Georgia location requires first order differencing, has one lagged price term, no moving average process, along with second order seasonal differencing, and three seasonally lagged price terms.

As Table 1 shows the estimated coefficients are all significantly different from zero. The lagged price terms (either non-seasonal or seasonal) all decline in value as is expected. In each location, this year's price is negatively related to prices in previous years. Since sockeye have a four year cycle from egg to spawner this cyclicity in prices is expected. As the season progresses prices are predicted to rise in the North, but fall in the West and Georgia locations. The greatest seasonal variation occurs in the Georgia location. This is consistent with the travel patterns of the salmon. They come from the Pacific Ocean, travel down the coast on a southerly route to spawn by and large in the southernmost part of the Georgia location. When they reach the rivers that lead them to their spawning grounds they stop eating and begin to lose weight. They are less desirable fish at this point. However, much of the Georgia catch takes place just around this time.

The Box-Ljung statistics are used to examine the residuals from the estimated models. The test statistics is distributed as a χ^2 with M—p—q degrees of freedom,

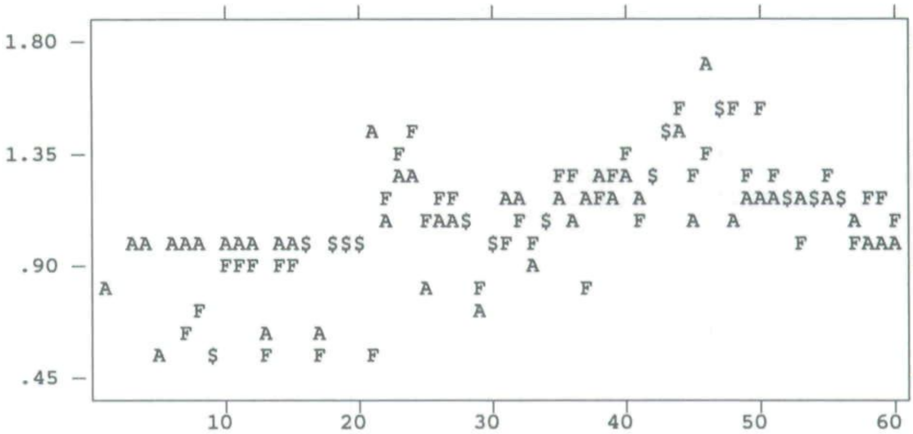

Figure 2. Plot of Actual and Forecast Prices for Sockeye Salmon. West Location—1968–1982, Seine Vessels.

Notes:
The following plot symbols are used:
A–Actual price (Real 1981 Collars)
F–Forecast Price
$–Where Forecast Price equals Actual Price

This price series has four periods in each year. Actual prices begin with period 1 in 1968 and continue to period 4 in 1982. Predictions begin with period 3 in 1969 (because of autoregressive components and the first differencing of the model) and continue to period 4 in 1982.

where M is the number of lagged residuals examined; p is the number of autoregressive lags, and q is the number of moving average terms. In order to accept the hypothesis of white noise, the calculated Box-Ljung statistic must be less than the critical value of χ^2. For North this critical value is 29.8 (13 degrees of freedom), for West and Georgia the critical value is 28.3 (12 degrees of freedom). In each case, the calculated Box-Ljung statistic at 16 lags is substantially smaller than the critical value at $\alpha = 0.005$ (*i.e.*, at a confidence level of 99.5%). Hence, these models have white noise residuals, *i.e.*, no further information can be incorporated into the estimates.

Since these ARIMA models are ultimately used to obtain predictions of 1982 prices, it is useful to have a summary statistic of how well they forecast. Theil's inequality coefficient is commonly used (Newbold and Bos, 1990). It is essentially a ratio of the mean squared error of the forecasts from the chosen model to the mean squared error of a series of one-step ahead naive forecasts. This statistic does not have a distribution, but it is bounded by 0 and 1 with smaller values indicating better forecast ability of the chosen model. The statistics for each of the regions are as follows: 0.4556 for North, 0.2809 for West, and 0.3937 for Georgia. Each of these is relatively small indicating good forecasts. However, it is possible to interpret the statistics in a more meaningful way. For example, for the North location, the mean squared error of the chosen model is 20% of the mean squared error of a naive (one-step ahead) forecast. Thus, one can have confidence in using

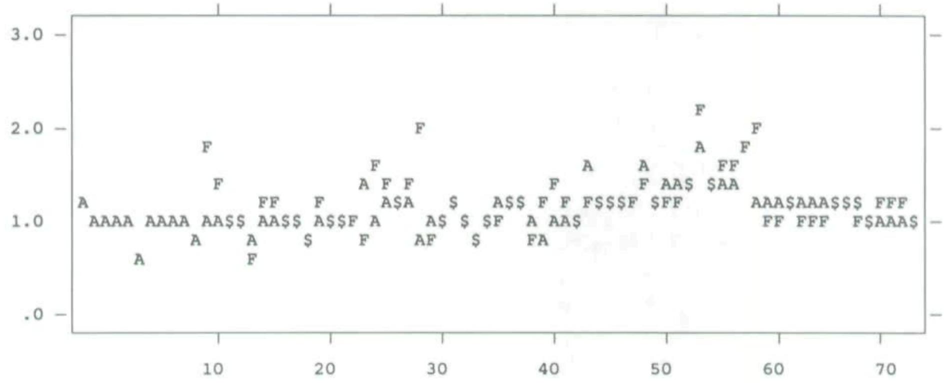

Figure 3. Plot of Actual and Forecast Prices for Sockeye Salmon. Georgia Location—1968–1982, Seine Vessels.

Notes:
The following plot symbols are used:
A–Actual Price (Real 1981 Dollars)
F–Forecast Price
$–Where Forecast Price equals Actual Price

This price series has five periods in each year. Actual prices begin with period 1 in 1968 and continue to period 5 in 1982. Predictions begin with period 2 in 1970 (because of the autoregressive component and the second order seasonal differencing of model) and continue to period 5 in 1982.

the forecast prices from these models as regressors in the estimation of the location-specific seasonal profit models.

Since the available data only permit the locational profit functions to be estimated for the season as a whole, but the price forecasts can be obtained for each period within the season, the forecasts are averaged to obtain an estimate of a seasonal price. This is done for each sub-species within each fishing location and for each vessel type. Finally, prior to estimation, a Divisia aggregate price index is constructed for each vessel using that vessel type's seasonal price estimate for each species.

Stage 2: Regional Profit Modelling and Estimation

In order to get estimates of expected seasonal profits according to each of the three fishing locations, I begin with a model of profit maximization behaviour. The fisher is assumed to maximize expected seasonal profit through his choices of salmon catch, identified in the following by the letter C, and three variable inputs (labour, fuel, and gear), identified in the following by the letters L, F, G.

Data from a 1982 cross-sectional survey of the British Columbia commercial fisheries are used to construct the variables used as regressors. The usable sample from the cross-sectional survey data is 245 salmon only fishing firms, about 5% of the total salmon fishing fleet. Data collected for each fishing firm include: actual prices received for landed salmon, quantities of fish caught, labour, energy, equipment, and capital input expenditures, vessel size, estimated market value of ves-

Table 1
Coefficient Values and Statistics for Three Seine Sockeye ARIMA Models

Arima Model Type[a] Coefficient	North (2,1,0) (1,0,0) Value[b]	T Stat[c]	West (2,1,0) (2,1,0) Value	T Stat	Georgia (1,1,0) (3,2,0) Value	T Stat
Φ_1	−.619	−4.740	−.727	−5.400	−.454	−4.200
Φ_2	−.273	−2.111	−.380	−2.836	na	na
θ_1	.615	6.143	−.500	−3.561	−.812	−6.486
θ_2	na	na	−.353	−2.505	−.512	−3.390
θ_3	na	na	na	na	−.355	−2.876
Log Likelihood Function Value		5.650		13.391		8.286
Box-Ljung (at 16 lags)		9.215		7.380		6.279

[a] See text for a detailed discussion of these models and explanations for the numbers in brackets.
[b] These are the estimated coefficent values.
[c] These are the t-statistics for the various estimated coefficients.
na not applicable. For example, the model for the North location does not require estimation of either the second or third seasonally lagged price term.

sel, an inventory of gear and equipment, region fished, and home port. For each fishing firm I have calculated an opportunity cost of labour in the manner discussed by Squires (1987) and Dupont (1990), as well as the Divisia input prices for equipment and capital, and a Divisia expected price index for the aggregate salmon catch. I obtained energy prices from Esso Canada. In addition, using information on catch and escapement I have estimated stock levels for each of the five species of salmon for 30 different management regions. The Department of Fisheries and Oceans kindly provided data obtained from sales brokers on the "market" values for fishing licenses.

I divided the 245 vessels in the survey into three samples, one for each of the three fishing locations. Vessels are included in a sample if the majority of fishing trips took place in that location.[10] In more than 90% of cases, vessels operate virtually all the season in a particular location, thereby indicating that switching within a season may be expensive or otherwise undesirable. The three locational samples contain 85 (Georgia), 84 (North Coast), and 76 (West Coast) observations. The breakdown of vessel types by each location is as follows: Georgia has 47 gillnetters, 14 gillnet-trollers, 15 seiners, and 9 trollers; North has 32 gillnetters, 33 gillnet-trollers, 3 seiners, and 16 trollers. Finally, the West region has 1 gillnetter, 13 gillnet-trollers, 3 seiners, and 59 trollers. While the North and Georgia regions have a fair distribution of vessel types, the West region is clearly not favoured by gillnetters in the sample of 245 vessels.

In the empirical work, I estimate a normalized quadratic seasonal profit function (π^R) for each of the regions. The function is normalized for this work by P_c (the catch price) and Z_s (the stock of fish). It is a flexible functional form with a

[10] The identical sample composition occurs when vessels are allocated to a sample according to a division based on revenue by location.

variety of useful features (Dupont, 1991).[11] For example, instead of estimating the profit function itself, the researcher can capture all parameters (including fixed factor ones) by estimating jointly the single output supply and three variable input demand equations.[12]

A second feature of the normalized quadratic is that the researcher can impose convexity in prices using the technique identified in Wiley, Bramble, and Schmidt (1973) without reducing the number of elasticities that can be obtained. However, the function becomes nonlinear in the price and cross-price parameters. Since initial estimates revealed some non-convexities, the curvature property is imposed upon the restricted profit function.

Rather, than show the restricted profit function, I show the actual estimating equations derived from it. Output supply (C^*) is shown in equation (7); labour demand (L^*) in equation (8), fuel demand (F^*) in equation (9), and gear demand (G^*) in equation (10). As shown, these equations are nonlinear and already have curvature imposed upon them.[13]

$$\frac{\partial \pi^R(P_C,P_L,P_F,P_G,Z_S,Z_T,Z_D)}{\partial P_C} = C^* = -\frac{1}{2}\sum_{j=1}^{3}\frac{\alpha_j Z_j}{P_C^2}\left[\left(A_1\left(\sum_{i=1,i\neq 2}^{4} R_i D_i\right)\right)^2 * P_L^2\right.$$

$$+ 2 * A_1\left(\sum_{i=1,i\neq 2}^{4} R_i D_i\right) * A_2\left(\sum_{i=1,i\neq 2}^{4} R_i D_i\right) * P_L P_F + 2 * A_1\left(\sum_{i=1,i\neq 2}^{4} R_i D_i\right)$$

$$* A_4\left(\sum_{i=1,i\neq 2}^{4} R_i D_i\right) * P_L P_G + \left(\left(A_2\left(\sum_{i=1,i\neq 2}^{4} R_i D_i\right)\right)^2 + \left(A_3\left(\sum_{i=1,i\neq 2}^{4} R_i D_i\right)\right)^2\right)$$

$$* P_F^2 + 2 * \left(A_3\left(\sum_{i=1,i\neq 2}^{4} R_i D_i\right) * A_5\left(\sum_{i=1,i\neq 2}^{4} R_i D_i\right) + A_2\left(\sum_{i=1,i\neq 2}^{4} R_i D_i\right)\right.$$

[11] As Lau (1985) points the normalized quadratic imposes input-output separability. This means that the marginal rates of transformation (substitution) are unaffected by the levels of the inputs (outputs). Given that output is aggregated, this is an unimportant feature of the normalized quadratic for this work.

[12] It is possible to estimate these equations jointly with the restricted profit function for increased efficiency. However, since the point estimates themselves and not their variances are of interest, this is not done. One potential difficulty with estimating the restricted profit function along with the input demands and output supply equations is the likelihood of multicollinearity given the large number of parameters in the restricted profit function equation. It is important to note, however, that if a translog functional form had been used instead, then one would have had to estimate the restricted profit function along with the input demand and output supply equations in order to get parameter values associated with the cross-fixed factor terms.

[13] The relationship between the linear coefficients and the nonlinear ones shown in equations (7)–(10) is as follows: $a_{LL} = A_1^2$, $a_{LF} = A_1A_2$, $a_{LG} = A_1A_4$, $a_{FF} = A_2^2 + A_3^2$, $a_{FG} = A_3A_5 + A_2A_4$, and a_{GG} and $A_4^2 + A_5^2 + A_6^2$. The a's are the linear counterparts to the nonlinear A's. The subscripts on the a's refer to labour (L), fuel (F), and gear (G).

$$* A_4\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right)\right) * P_FP_G + \left(\left(A_4\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right)\right)^2 + \left(A_5\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right)\right)^2$$

$$+ \left(A_6\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right)\right)^2\right) * P_G^2\Bigg] + \frac{1}{2}\beta_C \sum_{h=1}^{3}\sum_{j=1}^{3} D_{hj}\frac{Z_hZ_j}{Z_S} + \sum_{j=1}^{3} C_{Cj}Z_j$$

$$+ \beta_C \sum_{j=1}^{3} B_j \frac{Z_j}{Z_S} + \frac{1}{2}\frac{B_0\beta_C}{Z_S} + C_C\left(\sum_{i=5,i\neq 6}^{8} R_iD_i\right) \text{ where } h,j = S,T,D \tag{7}$$

$$\frac{\partial\pi^R(P_C,P_L,P_F,P_G,Z_S,Z_T,Z_D)}{\partial P_L} = L^* = \sum_{j=1}^{3}\alpha_j\frac{Z_j}{P_C} * \left[\left(A_1\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right)\right)^2 * P_L\right.$$

$$+ A_1\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right) * A_2\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right) * P_F + A_1\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right)$$

$$\left. * A_4\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right) * P_G\right] + \frac{1}{2}\beta_L \sum_{h=1}^{3}\sum_{j=1}^{3} D_{hj}\frac{Z_hZ_j}{Z_S} + \sum_{j=1}^{3} C_{Lj}Z_j$$

$$+ \beta_L \sum_{j=1}^{3} B_j \frac{Z_j}{Z_S} + \frac{1}{2}\frac{B_0\beta_L}{Z_S} + C_L\left(\sum_{i=5,i\neq 6}^{8} R_iD_i\right) \tag{8}$$

$$\frac{\partial\pi^R(P_C,P_L,P_F,P_G,Z_S,Z_T,Z_D)}{\partial P_F} = F^* = \sum_{j=1}^{3}\alpha_j\frac{Z_j}{P_C} * \left[A_1\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right)\right.$$

$$* A_2\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right) * P_L + \left(\left(A_2\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right)\right)^2 + \left(A_3\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right)\right)^2\right)$$

$$* P_F + \left(A_3\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right) * A_5\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right) + A_2\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right)\right.$$

$$* A_4\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right)\Bigg)\Bigg) * P_G\Bigg] + \frac{1}{2}\beta_F \sum_{h=1}^{3}\sum_{j=1}^{3} D_{hj}\frac{Z_hZ_j}{Z_S} + \sum_{j=1}^{3} C_{Fj}Z_j$$

$$+ \beta_F \sum_{j=1}^{3} B_j \frac{Z_j}{Z_S} + \frac{1}{2}\frac{B_0\beta_F}{Z_S} + C_F\left(\sum_{i=5,i\neq 6}^{8} R_iD_i\right) \tag{9}$$

$$\frac{\partial\pi^R(P_C,P_L,P_F,P_G,Z_S,Z_T,Z_D)}{\partial P_G} = G^* = \sum_{j=1}^{3}\alpha_j\frac{Z_j}{P_C} * \Bigg[A_1\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right)$$

$$* A_4\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right) * P_L + \left(A_3\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right) * A_5\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right)\right.$$

$$+ A_2\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right) * A_4\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right)\Bigg) * P_F + \Bigg(\left(A_4\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right)\right)^2$$

$$+ \left(A_5\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right)\right)^2 \left(A_6\left(\sum_{i=1,i\neq 2}^{4} R_iD_i\right)\right)^2\Bigg) * P_G\Bigg] + \frac{1}{2}\beta_G \sum_{h=1}^{3}\sum_{j=1}^{3} D_{hj}\frac{Z_hZ_j}{Z_S}$$

$$+ \sum_{j=1}^{3} C_{Gj}Z_j + \beta_G \sum_{j=1}^{3} B_j \frac{Z_j}{Z_S} + \frac{1}{2}\frac{B_0\beta_G}{Z_S} + C_G\left(\sum_{i=5,i\neq 6}^{8} R_iD_i\right) \tag{10}$$

Each of these four equations depends upon the aggregate ARIMA forecasted price for salmon catch (P^*_c), the actual prices of the labour, fuel, and gear variable inputs (P_L, P_F, and P_G) and a vector of fixed inputs including the fish stock, Z_S, the size or tonnage of the vessel, Z_T, and the number of restricted fishing days, Z_D. These latter take account of the current harvesting restrictions imposed upon participants in the fishery. In all, the regressors include the prices themselves, their squared terms and cross-price terms, as well as the fixed factors, their squared terms, and their cross-factor terms. The coefficients to be estimated are: A_1, A_2, A_3, A_4, A_5, A_6; D_{hj} for h = S, T, D, and j = S, T, D; C_{ij} for i = C, L, F, G and j = S, T, D; B_j for j = T, D, B_0, and C_i for i = C, L, F, G. The α_j and β_i are prespecified coefficients equal respectively to $1/Z^1{}_j$ which is the fixed factor vector for the first observation and $1/P^1{}_i$ which is the price vector for the first observation (Dupont, 1990).

Based on the breakdown of vessel types by region, there are insufficient data points in each sample to estimate vessel-type specific locational profit functions, so in order to incorporate likely differences in the estimated parameters dummy variables for gear types are added to the price terms and to the constant terms of equations (7)–(10). This assumes that whatever differences exist between the vessel types in a given region are confined only to the price (slope) and constant (intercept) terms. The dummy variables are D_1 through D_4. D_1 corresponds to the gillnet vessel type and takes a value of 1 if the observation is from a gillnet vessel and 0 otherwise. D_2 corresponds to the gillnet-troll vessel, but this vessel is chosen as the numeraire vessel, so this dummy is dropped. D_3 represents the seine and D_4 the troll vessel types. In total, there are six dummy variable coefficients (R_1, R_3, R_4, R_5, R_7, and R_8) to be estimated. R1 and R5 are coefficients for the gillnet vessel (the first parameter is used in the price terms and the second in the constant term). R3 and R7 are coefficients for the seine vessel and R4 and R8 are the corresponding coefficients for the troll vessel.

Equations (7)–(10) are estimated for each of the three samples. Since curvature is imposed and the equations have cross equation parameter restrictions, a non-linear 3 stage least squares procedure with a Davidson-Fletcher-Powell algorithm is used to find parameter estimates (White, 1978; SHAZAM, 1993). A convergence criterion of 0.00001 is adopted.

Tables 2–4 give coefficient values, standard errors, t-statistics, the value of the log-likelihood function and a R^2 value between the actual and predicted values for each of the four equations estimated. Estimation results are best for the Georgia and North regions according to the number of significant coefficients. Coefficients on parameters including the price terms are generally significantly different from zero, as are the coefficients on parameters relating to tonnage and number of fishing days, particularly when the variable input is fuel.[14] In addition, the dummy variables tend to be more significant in the North and Georgia locations which would correspond to the fact that there is a greater dispersion of vessel types operating in these locations. The fact that only a single gillnet vessel operated in the West region in 1982 may contribute to the poorer results for this region. However, prices are clearly important in the West region and there is an indication that coefficients relating to fuel prices are particularly significant. Since this region lies to the west of Vancouver Island fishers operate in open ocean, one might expect to find this result. The calculated R^2 values range between a low of 0.0943 for the gear equation in the North region to a high of 0.5470 for the catch equation in the North region. The average R^2 value is around 0.3756 which is quite a good result for cross-sectional data. On average the gear equations perform the worst. A possible explanation is that gear is not as malleable an input as are fuel and labour for these vessels.

Using the estimated parameter values for each locational profit function, location average prices for inputs, price forecasts for output, and fisher-specific information on the size of vessel and number of fishing days, I construct the seasonal profit each fisher could expect to earn in each of the three fishing locations.[15] The variance of the expected profit is calculated in the following way. I

[14] The values of these coefficients, like all coefficients estimated for a flexible functional form, do not have an obvious interpretation. Rather, subsets of the coefficients are used to calculate input and output elasticities. These elasticities, however, are not the main thrust of the paper.

[15] This assumes that a fisher could transfer operations to a location other than the one in which he has been observed fishing. Given that vessels of all four types are found in each location, this is a reasonable assumption.

Table 2
Regression Results for Georgia Location

	Coefficient	St. Error	T-Ratio
A_1	−26.10	6.74	−3.87
A_2	−14.69	8.78	−1.67
A_3	−25.62	13.57	−1.89
A_4	−3.12	13.68	−0.23
A_5	−2.39	12.11	−0.20
A_6	−12.66	15.89	−0.80
R_1	3.49	7.02	0.50
R_3	18.65	9.49	1.97
R_4	0.83	4.38	0.19
R_5	9832.50	6379.20	1.54
R_7	20668.00	7844.40	2.63
R_8	54.96	5887.10	0.93E − 02
D_{TT}	598.52	369.59	1.62
D_{DD}	−21.81	39.15	−0.56
D_{TD}	32.88	111.39	0.30
B_O	933.06	12675.00	0.73E − 01
B_T	−1064.70	1626.40	−0.65
B_D	219.98	853.26	0.26
C_{CS}	7518.80	23857.00	0.32
C_{CT}	7308.40	4185.60	1.75
C_{CD}	3465.10	1754.90	1.97
C_C	−5685.30	27084.00	−0.21
C_{LS}	−4400.80	8404.60	−0.52
C_{LT}	−5301.00	2035.40	−2.60
C_{LD}	−1294.50	774.63	−1.67
C_L	−9947.00	11645.00	−0.85
C_{FS}	1062.10	8875.10	0.12
C_{FT}	−6248.20	2077.80	−3.01
C_{FD}	−1171.90	914.89	−1.28
C_F	−11334.00	12206.00	−0.93
C_{GS}	0.3E + 06	0.23E + 06	1.48
C_{GT}	−23733.00	32053.00	−0.74
C_{GD}	−3&110.00	12214.00	−2.96
C_G	−0.18E + 06	0.24E + 06	−0.75

Log-Likelihood Function = 55.24
R^2 (Catch) = 0.5528 R^2 (Fuel) = 0.4130
R^2 (Labour) = 0.5117 R^2 (Gear) = 0.3484

Table 3
Regression Results for North Location

	Coefficient	St. Error	T-Ratio
A_1	24.67	7.89	3.13
A_2	4.83	10.85	0.45
A_3	44.86	12.11	3.70
A_4	51.15	15.45	3.31
A_5	41.20	15.96	2.58
A_6	47.84	183.09	0.26
R_1	−47.44	13.47	−3.52
R_3	−39.09	17.94	−2.17
R_4	−48.77	14.41	−3.38
R_5	492.94	2438.30	0.20
R_7	12395.00	11367.00	1.09
R_8	−723.52	4360.50	−0.17
D_{TT}	5059.80	1998.80	2.53
D_{DD}	−16.30	46.22	−0.35
D_{TD}	−128.85	337.19	−0.38
B_O	−2189.30	7056.80	−0.31
B_T	1175.30	5342.20	0.22
B_D	−51.33	366.08	−0.14
C_{CS}	6620.70	9027.60	0.73
C_{CT}	6135.10	10054.00	0.61
C_{CD}	2924.10	1985.00	1.47
C_C	13581.00	13847.00	0.98
C_{LS}	754.05	3543.80	0.21
C_{LT}	−17323.00	5197.10	−3.33
C_{LD}	−821.18	1069.90	−0.77
C_L	−2064.50	5849.40	−0.35
C_{FS}	−601.46	3559.50	−0.17
C_{FT}	−18261.00	5342.50	−3.41
C_{FD}	−2780.30	1465.50	−1.90
C_F	1033.70	6060.70	0.17
C_{GS}	−45048.00	64834.00	−0.69
C_{GT}	−29710.00	45770.00	−0.65
C_{GD}	−15553.00	7277.50	−2.14
C_G	48848.00	80868.00	0.60

Log-Likelihood Function = 50.60
R^2 (Catch) = 0.5470 R^2 (Fuel) = 0.3454
R^2 (Labour) = 0.3775 R^2 (Gear) = 0.0943

Table 4
Regression Results for West Location

	Coefficient	St. Error	T-Ratio
A_1	24.84	13.32	1.86
A_2	−7.41	34.22	−0.22
A_3	−106.88	25.56	−4.11
A_4	0.32	1.44	0.22
A_5	0.98	1.28	0.77
A_6	0.88	13.51	0.65E − 01
R_1	0.84	6.13	0.14
R_3	−0.95	1.27	−0.75
R_4	−0.78	1.23	−0.63
R_5	9421.10	15064.00	0.63
R_7	3752.80	18529.00	0.20
R_8	11585.00	7760.40	1.49
D_{TT}	3529.10	3710.60	0.95
D_{DD}	1518.30	2282.60	0.67
D_{TD}	2288.70	3402.70	0.67
B_O	5333.50	24427.00	0.22
B_T	−21276.00	24556.00	−0.87
B_D	−1714.80	6215.70	−0.28
C_{CS}	4047.10	27999.00	0.14
C_{CT}	33007.00	32053.00	1.03
C_{CD}	844.63	13768.00	0.61E − 01
C_C	16806.00	50595.00	0.33
C_{LS}	−3626.90	7113.10	−0.51
C_{LF}	8161.40	19784.00	0.41
C_{LG}	−4065.20	4028.70	−1.01
C_L	−9636.50	17540.00	−0.55
C_{FS}	−11104.00	8679.60	−1.28
C_{FT}	−11998.00	20626.00	−0.58
C_{FD}	−12841.00	5703.00	−2.25
C_F	−10651.00	18252.00	−0.58
C_{GS}	−3464.40	7356.50	−0.47
C_{GT}	11174.00	20304.00	0.55
C_{GD}	−6396.60	3625.60	−1.76
C_G	4337.20	17965.00	0.24

Log-Likelihood Function = 45.07

R^2 (Catch) = 0.2012 R^2 (Fuel) = 0.4859

R^2 (Labour) = 0.5049 R^2 (Gear) = 0.1256

Table 5
Summary Statistics on Expected Profits, Expected Wealth and their Variances

	Georgia Location				
Variable	Min.[a]	Max.[a]	Mean	Median	St. Dev.[a]
Expected Profit[b]	−7.0	58.8	21.0	19.2	12.7
Expected Wealth[b]	17.8	621.8	153.7	105.3	131.8
Variance of Expected Profit	0.1E − 2	0.5E − 2	0.2E − 2	0.2E − 2	0.8E − 3
Variance of Expected Wealth	0.2E − 13	0.2E − 10	0.2E − 11	0.1E − 11	0.4E − 11

[a] Min. is the minimum value taken by the variable, Max. is the maximum value and St. Dev. is the standard deviation of the variable.
[b] Expected Profits and Expected Wealth are in thousands of 1982 dollars.

assume that the variance of profit can be proxied by a weighted linear function of the variances of the five forecast prices with weights equal to the fisher's revenue share for each sub-species.[16] Information on the variances of the five forecast prices comes from the standard errors of the ARIMA estimates for each price series.

Since the paper is interested in comparing the location decision choices made according to considerations of not only expected profit and its variability, but also expected wealth and its variability, an estimate of pre-season wealth is needed for the latter model. Pre-season wealth is obtained from the Survey of fishers and taken to be the sum of the market value of the fishing vessel, other fixed equipment, and the estimated market value of the fishing license obtained from the Department of Fisheries and Oceans.[17] Pre-season wealth is assumed to be invariant to the choice of the current season's fishing location.

Tables 5–7 provide summary statistics on the values of the expected profit and wealth and the variances of expected profits and wealth by fishing location. Expected profit is the sum of pre-season wealth and expected profit. The variance of expected wealth is calculated according to the second term on the right hand side of equation (5) (Opaluch and Bockstael, 1983). Clearly, there is a lot of variation in expected profit and expected wealth, but less variation in the variances of these two variables.

[16] Ideally, the weights should be the expected revenue shares, however, this would require a multi-output model that would predict how the catches of the five sub-species would respond to differential forecast prices. Since the locational model estimated employs a single output specification for reasons of parameter parsimony, I cannot predict these expected revenues shares. As proxies, I use the actual 1982 shares.
[17] The fishery under examination operates as a restricted access fishery. Participants must be in possession of a fishing license that is attached to a specific fishing vessel. There are fewer licenses available than there is demand for them. Over the years, these licenses have gained in value because of the presence of fishery rents. Although the Department of Fisheries and Oceans prohibits the trading of licenses by themselves, sales of licenses do take place when fishing vessels change hands. The Department has collected information from sales brokers that gives an estimate of the average license value according to the tonnage (vessel size). In the paper, it is assumed that the pre-1982 season value or spring 1982 season value is appropriate. For seine vessels, this is estimated at $4,500 per imperial net ton and for all other vessels, $3,500.

Table 6
Summary Statistics on Expected Profits, Expected Wealth and their Variances

Variable	Min.[a]	Max.[a]	Mean	Median	St. Dev.[a]
		North Location			
Expected Profit[b]	−1.9	108.1	17.3	15.9	15.6
Expected Wealth[b]	12.7	368.9	110.3	96.3	75.9
Variance of Expected Profit	0.8E − 3	0.4E − 2	0.2E − 2	0.2E − 2	0.8E − 3
Variance of Expected Wealth	0.3E − 13	0.6E − 10	0.5E − 11	0.9E − 12	0.1E − 10

[a] Min. is the minimum value taken by the variable, Max. is the maximum value and St. Dev. is the standard deviation of the variable.
[b] Expected Profits and Expected Wealth are in thousands of 1982 dollars.

Discrete Choice Model Results

The final stage of this analysis is the estimation of four different multinomial logit models using two versions of the utility function of equation (5). In each case a likelihood function like equation (5) is formulated and estimated using a nonlinear maximum likelihood technique using Newton's method (Berndt, Hall, Hall, and Hausman, 1974). For each model, observations on 245 fishers' location choices are used and each model allows for the choice of one of three locations. Model 1 postulates that expected utility is a function of expected profit and its variability. Model 2 adds pre-season wealth to expected profitability. Each model (1 and 2) is estimated twice to create version A and version B. The A versions pool all observations and hypothesize that all vessel types respond identically to either expected profit and its variability (Model 1A) or to expected wealth and its variability (Model 2A). In each of Model 1A and 2A two coefficients are estimated—the first explains how fishers respond to expected profit (or wealth) and the second how fishers respond to variability. Models 1B and 2B extend the analysis to allow for differences in the responses through the inclusion of dummy interaction terms with expected profit for wealth) and its variability. These extended models contain 8 coefficients to be estimated. Table 8 presents an overview of the four models estimated.

Results for Model 1A are shown in Table 9, for Model 2A in Table 10, for Model 1B in Table 11 and for Model 2B in Table 12. In each case, results are shown for a likelihood ratio test comparing the value of the likelihood function

Table 7
Summary Statistics on Expected Profits, Expected Wealth and their Variances

Variable	Min.[a]	Max.[a]	Mean	Median	St. Dev.[a]
		West Location			
Expected Profit[b]	−26.9	76.3	9.4	9.5	16.3
Expected Wealth[b]	32.6	898.3	177.8	143.9	144.0
Variance of Expected Profit	0.8E − 3	0.3E − 2	0.1E − 2	0.1E − 2	0.5E − 3
Variance of Expected Wealth	0.1E − 13	0.4E − 11	0.5E − 12	0.3E − 12	0.6E − 12

[a] Min. is the minimum value taken by the variable, Max. is the maximum value and St. Dev. is the standard deviation of the variable.
[b] Expected Profits and Expected Wealth are in thousands of 1982 dollars.

Table 8
Overview of Logit Models Estimated

Version	Model Number 1	2
A	Hypotheses: Determinants of location choice are: —EXPECTED PROFIT (with pos. sign) —VARIANCE OF EXPECTED PROFIT (with neg. sign) Assumption: —ALL VESSEL TYPES HAVE SAME RESPONSE	Hypotheses: Determinants of location choice are: —EXPECTED WEALTH (with pos. sign) —VARIANCE OF EXPECTED WEALTH (with neg. sign) Assumption: —ALL VESSEL TYPES HAVE SAME RESPONSE
B	Hypotheses: Determinants of location choice are: —EXPECTED PROFIT (with pos. sign) —VARIANCE OF EXPECTED PROFIT (with neg. sign) Assumption: —EACH OF FOUR VESSEL TYPES HAS DIFFERENT COEFFICIENT ON EXPECTED PROFIT AND VARIANCE OF EXPECTED PROFIT	Hypotheses: Determinants of location choice are: — EXPECTED WEALTH (with neg. sign) —VARIANCE OF EXPECTED WEALTH (with neg. sign) Assumption: —EACH OF FOUR VESSEL TYPES HAS DIFFERENT COEFFICIENT ON EXPECTED WEALTH AND VARIANCE OF EXPECTED WEALTH

when the two (or eight) coefficients are freely estimated to the value of the likelihood function when the coefficients are restricted to be zero. The null hypothesis in this case is that the coefficients are not jointly significantly different from zero, i.e., that the model has no explanatory power. However, the likelihood ratio test suggests that the parameters are jointly significantly different from zero at a confidence level greater than 99.9. The null hypothesis is clearly rejected by the data.

Comparison of Models 1A and 1B

Models 1A and 1B differ in the definition of what determines expected utility. A comparison of the results from these two models is interesting because it can provide information as to whether fishers' location decisions are subject to wealth or stock effects. The sign on the expected profit or wealth coefficient is interpreted as follows: it says that as the expected profit (wealth) from one location

Table 9
Multinomial Logit Model Estimation Results—Model 1A

	Coefficient	St. Error	T-Ratio
Expected Profit	0.3342	0.0683	4.892
Variance of expected profit	0.000001	0.000007	0.138

Log-likelihood function = −102.72
Log-likelihood (assuming coefficients are zero) = −269.16
Value of Chi-squared statistic (with 2 degrees of freedom) = 332.87

increases relative to the others, ceteris paribus, the probability of the fisher choosing that location increases relative to the probability of choosing the others. The larger the magnitude of the coefficient, the higher the probability of choosing the location. The coefficient on variability of returns is interpreted in the following way: if it is negative, this suggests that fishers prefer alternatives with less variation around expected returns, ceteris paribus. On the other hand, if the coefficient is positive, this says that fishers prefers alternatives with more variation around the expected return, ceteris paribus. In the first case, the fisher is a risk-averse individual; in the second, a risk-lover. The bigger the positive sign, the more the fisher is willing to take risks.

Both models show a positive sign for the expected profit (or wealth) variable and these coefficient values are both highly significantly different from zero. In addition, both models show a positive, although very small, sign for variability. In Model 1A the coefficient is not significantly different from zero, however, this is not the case in Model 2A. *A priori* one would expect a negative sign on the variability coefficient (Anderson, 1982 and Bockstael and Opaluch, 1983), thereby indicating that fishers are risk-averse. The results from this estimation show that, when expected profit alone is used to define wealth, fishers as a whole in this fishery are risk-neutral. Once pre-season wealth is included in the definition of utility, fishers become risk-loving, although the value of the coefficient is very small. Taken together, these results suggest that fishers become more risk-loving the higher their stock of wealth. These results provide evidence for the folklore about fishers being risk-lovers and willing to take chances.

Comparison of Models 2A and 2B

In order to investigate the phenomenon of risk-loving fishers in more detail, Models 2A and 2B are estimated. These models include dummy variable interac-

Table 10
Multinomial Logit Model Estimation Results—Model 2A

	Coefficient	St. Error	T-Ratio
Expected Wealth	66.0237	0.0760	866.341
Variance of expected wealth	0.00056	0.000009	615.096

Log-likelihood function = −255.51
Log-likelihood (assuming coefficients are zero) = −269.16
Value of Chi-squared statistic (with 2 degrees of freedom) = 27.309

Table 11
Multinomial Logit Model Estimation Results—Model 1B

	Coefficient	St. Error	T-Ratio
Seine			
Exp. Profit[a]	0.0068	0.0027	2.5550
Variance of Exp. Profit[a]	−0.1726	0.1078	−1.6010
Gillnet			
Exp. Profit	0.0329	0.0148	2.2210
Variance of Exp. Profit	−0.0605	0.0378	−1.6020
Gillnet-Troll			
Exp. Profit	0.0230	0.0344	0.6680
Variance of Exp. Profit	0.2655	0.2277	1.1660
Troll			
Exp. Profit	0.0311	0.0145	2.1450
Variance of Exp. Profit	0.000003	0.000003	1.0000

Log-likelihood function = −69.419
Log-likelihood (assuming coefficients are zero) = −269.16
Value of chi-squared statistic (with 8 degrees of freedom) = 399.48

[a] EXP. is the abbreviation for expected.

tion terms in the original two regressors to allow vessel-type specific coefficients on expected profit (or wealth) and its variability to be obtained for each of the four vessel types in the fishery. The four kinds of vessels (seine, gillnet, troll, and gillnet-troll) use different types of gear and also exhibit differences in both the average size of the operation and the mix of salmon output caught. Seine vessels

Table 12
Multinomial Logit Model Estimation Results—Model 2B

	Coefficient	St. Error	T-Ratio
Seine			
Exp. Wealth[a]	1.3666	0.0631	21.673
Variance of Exp. Wealth[a]	11.1131	1.4215	7.818
Gillnet			
Exp. Wealth	0.8259	0.0155	53.220
Variance of Exp. Wealth	−0.0361	0.0139	−2.594
Gillnet-Troll			
Exp. Wealth	0.4840	0.0174	27.878
Variance of Exp. Wealth	−0.0143	0.0074	−1.944
Troll			
Exp. Wealth	1.7292	0.0311	55.535
Variance of Exp. Wealth	−2.5908	0.0740	−34.999

Log-likelihood function = −244.81
Log-likelihood (assuming coefficients are zero) = −269.16
Value of chi-squared statistic (with 8 degrees of freedom) = 48.706

[a] Exp. is the abbreviation for expected.

are largest, gillnet vessels are smallest.[18] Gillnet-troll vessels are most flexible since they carry two types of gear. A larger number of troll vessels tend to fish in the roughest locations and on the open ocean.

Model 1B has three coefficients that are all significantly different from zero at a 90% probability level, although the values of the coefficients are small (all less than 0.1). These are the coefficients on expected profit for the seine, gillnet, and troll vessels. They are all of the expected sign (positive). The gillnet-troll vessel coefficient on expected profit is of the correct sign but is not significantly different from zero. The coefficients on variability for the seine and gillnet vessels have the expected negative sign and are significantly different from zero or a probability level of 88%. The coefficients on variability for the troll and gillnet-troll vessels are positive but not significantly different from zero. Taken together these results suggest that expected profit is a much more important determinant than variability for most vessels. Furthermore, seine and gillnet vessels appear to be weak risk-averters, whereas gillnet-troll and troll vessels are willing to take somewhat greater risks.

Once pre-season wealth is added to expected profit (Model 2B) all coefficients become much larger than in Model 1B and all are highly significantly different from zero. In each case, the coefficients on expected wealth are of the expected positive sign. That is, the higher the expected wealth from a given location, the higher the probability that the fisher will choose the location, ceteris paribus. For three of the four vessels, there is an interesting reversal of the signs on the coefficient for variability. Seine vessel owners become risk-lovers (positive coefficient and very large and significantly different from zero) and gillnet-troll and troll vessel owners become risk-averters. Gillnet vessel owners continue as risk-averters but are less strongly oriented in that direction.

Seine vessels have the largest pre-season wealth of all vessel types. According to the results from these two models, this large cushion of wealth will turn what would be risk-averting behaviour (Model 1B where only expected profit is concerned) into risk-loving behaviour (Model 2B). The expected profit gain or loss is small relative to the existing stock of wealth, so the seine vessel owner is willing to accept more risk in exchange for the potential of a higher return. Seine vessel owners have invested in powerful engines, thereby enabling them to move around the fishing ground with relative ease in search of the most advantageous situations. Gillnet vessels have a very small pre-season wealth and most vessels are owner operated. Furthermore, while these vessel owners may have outstanding debts, they are on average not large because there are few investments that can be made to these vessels and gear and equipment costs are relatively small. However, their owner-operator status is probably the main reason why they continue to be risk-averters, although, to a slightly lesser extent in Model 2B (the coefficient value on variability is -0.0361 compared to -0.0605 in Model 1B). So, even for these vessel types, there is a positive wealth (or stock) effect in regard to risk.

The troll and gillnet-troll vessels respond to increased returns in the opposite manner to the seine and gillnet vessels. When pre-season wealth is included in the

[18] Another way to examine the issue of heterogeneity of responses by vessels would be to include tonnage as an explanatory variables. This proved impossible to do along with the dummy variable interaction terms for vessel-specific type coefficients. There was too much correlation between tonnage and the breakdown by vessel type.

definition of utility, troll and gillnet-troll vessel owners exhibit strong risk-averting behaviour. Even though gillnet-troll vessel owners are risk-averse, they care more about their expected return because the coefficient on expected wealth is much larger than that on variability. This may explain why gillnet-trollers employ the type of fishing vessel that enables them to use both net and hook and line equipment, thereby giving them the flexibility to attain the best possible return on their efforts. The multi-gear decision is likely in response to government regulations on the type of equipment that can be used in certain fishing locations at specific times of the season.

For the troll vessel type, the coefficient on variability of wealth has a larger absolute value than the coefficient on expected wealth. The presence of more wealth for these vessel owners means more cautious behaviour. Unlike the gillnet vessel owners, these vessel owners tend to have overcapitalized and many have very heavy debt loads. Since much of the wealth of these fishers is tied up in their boats (as opposed to the fishing licences), they become more risk-averse the more expensive the boat and equipment (the bigger the stock effect). In other words, greater wealth on paper also means a larger debt load. A good return during the fishing season is important to help pay any outstanding debt on vessel and equipment loans. Thus, they are less likely to take risks than if they were only concerned with current return and not the overall state of wealth.[19]

There are two final comments that can be made in regard to the results found in this paper. First, the results indicating risk-loving behaviour under some circumstances by some groups does not refute the usefulness of the logarithmic utility function specification. The results in this paper are an empirical finding and are a function of the data used. That is to say, these results might not be found in other fisheries. However, the results do suggest risk-loving, risk-neutral, and risk-averse behaviour are all consistent with observations of the British Columbia salmon fishery. In other words, the population of fishers is heterogeneous as one would expect by observing different choices of vessel type, crew size, fishing location, and other items of choice. These results also suggest that there is much scope for further work in the area.

Second, these results may arise from so-called "habit persistence" which may be related to the high costs of switching from one location to another. If habit

[19] One reviewer expressed concern regarding the ownership patterns of the vessels. For example, what is the impact of processor ownership on the calculation of pre-season wealth? Unfortunately, the survey data do not provide this type of information and it has been impossible to obtain from any other sources. Pearse (1982) claims that most of the salmon fleet is owned by individual vessel owners. For 1982, he cites a statistic indicating that 11% of licensed salmon vessels are owned by processors. However, prior to the 1982 fishing season, the largest processor divested itself of about 250 vessels. So, this number would fall to about 9% for 1982. Pearse suggests that most gillnet vessels are owner operated, as are most gillnet-trollers, but that a number of seiners and trollers have some processor ownership. For those vessels in my sample for which processor ownership is the case, then the estimate of pre-season wealth is an underestimate from the point of the processing company. However, it is an overestimate from the point of the skipper hired by the processor and given autonomy to make fishing location choices. Clearly, this will mean a bias in the parameter estimates, but without knowing the exact ownership structure, along with the degree of autonomy given to hired skippers, it is impossible to determine the nature of the bias. Given the small percentage of processor ownership cited by Pearse (1982) this bias is likely to be very small.

persistence is indeed important then one might find risk-loving behaviour simply because fishers disregard the variability of returns in order to stay in a particular location. In order to examine this hypothesis simple counts of the number of vessels with a homeport in the chosen fishing location are taken. In the North location 52 vessels of 84 have homeports in the North location. In Georgia 62 of 85 vessels have a homeport in that location. But, in the West location, only 17 vessels claim a homeport in the West location. In general, as one would expect, the smaller, less powerful gillnet vessels display more habit persistence. However, the single gillnet vessel that chose to fish in the West location has a home port in Georgia. The larger trollers, seiners, and gillnet-trollers, on the other hand, exhibit less habit persistence. Thus, these results give some limited support to the habit persistence hypothesis. A complete test of the habit persistence hypothesis would require at least two years of data. Then, a dummy variable could be added to the regressors representing whether the same location choice had been made in the previous year. Another factor that may be important is the fact that many of the landing ports and most of the processing facilities are to be found especially in Georgia, and to a lesser extent in the North location. This may raise the cost of switching from one location to another and discourage fishers from these locations from choosing to fish in the alternative locations.

Conclusions and Policy Discussion

This paper makes several contributions to the applied fisheries literature and particularly to those aspects relating to uncertainty. First, it incorporates the use of ARIMA price forecasts into a model of decision-making behaviour of fishers. These ARIMA models are found to explain the price series well. Second, using these forecasts, along with a series of estimates for restricted profit functions, the paper calculates explicit expected locational profits and their variances for each vessel in the study. Third, the paper separates out the effects of expected profit and expected wealth upon the fishing location choices that fishers in the British Columbia commercial salmon fishery are observed to take. The four multinomial logit models estimated exhibit the importance of two factors in the explanation of location choice. First, there are significant differences in behaviour according to whether a wealth or stock effect is incorporated into the analysis. Second, it is important to account for vessel type differences in the coefficients to be estimated. The model that treats all vessel types as having identical responses tends to mask very different types of behaviour across different vessel types. Finally, the paper provides the first evidence to support the folklore that fishers may be risk-loving.

There are two policy implications arising from this work. The first policy implication is that fishers respond to economic incentives such as expected profits or wealth and their variability. Thus, a model of this type may be useful to fisheries managers in two ways. First, fisheries managers could use the results to predict fishing activity by region on the basis of expected prices. This data could be used to make more informed decisions about openings and closings of particular fishing grounds. Second, Pearse in the 1982 Royal Commission that studied Pacific Coast fisheries discussed the possibility of area licensing for the salmon fishery. He proposed three regions (corresponding to the three regions in this paper) be identified and that fishers would be required to hold a license to fish in a particular region. The results from this paper could be used to predict the demand for licenses in each area and allow fisheries managers to make better forecasts of activity and how fishers would distribute themselves. Furthermore, the results from this type of model could be used to predict how fishers would react to changing economic incentives in different regions. For example, if fisheries managers wished to effect a redistribution of effort by location, they could implement a series of location-specific royalty taxes that would alter the expected returns.

A second policy implication is the finding that fishers may indeed be risk-lovers. While this finding is specific to this particular fishery and others (Bockstael and Opaluch, 1983) have found risk-averse behaviour in a New England fishery, there are some aspects of this finding that could be important for fisheries managers. For example, the literature that compares the benefits of wage contracts to crop-share contracts assumes that fishers are risk-averse and, therefore, prefer crop-share contracts (Sutinen, 1979; Plourde and Smith, 1989). If vessel owners are truly risk-lovers, then this result no longer stands. This has implications for the structure of the fishing labour market. Given the concern today about overfishing and rationalization of existing commercial fisheries, this aspect is likely to be very important in any restructing of a fishery.

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