The Demand For Atlantic Salmon in Canada: Issues of Functional Form and Parameter Stability

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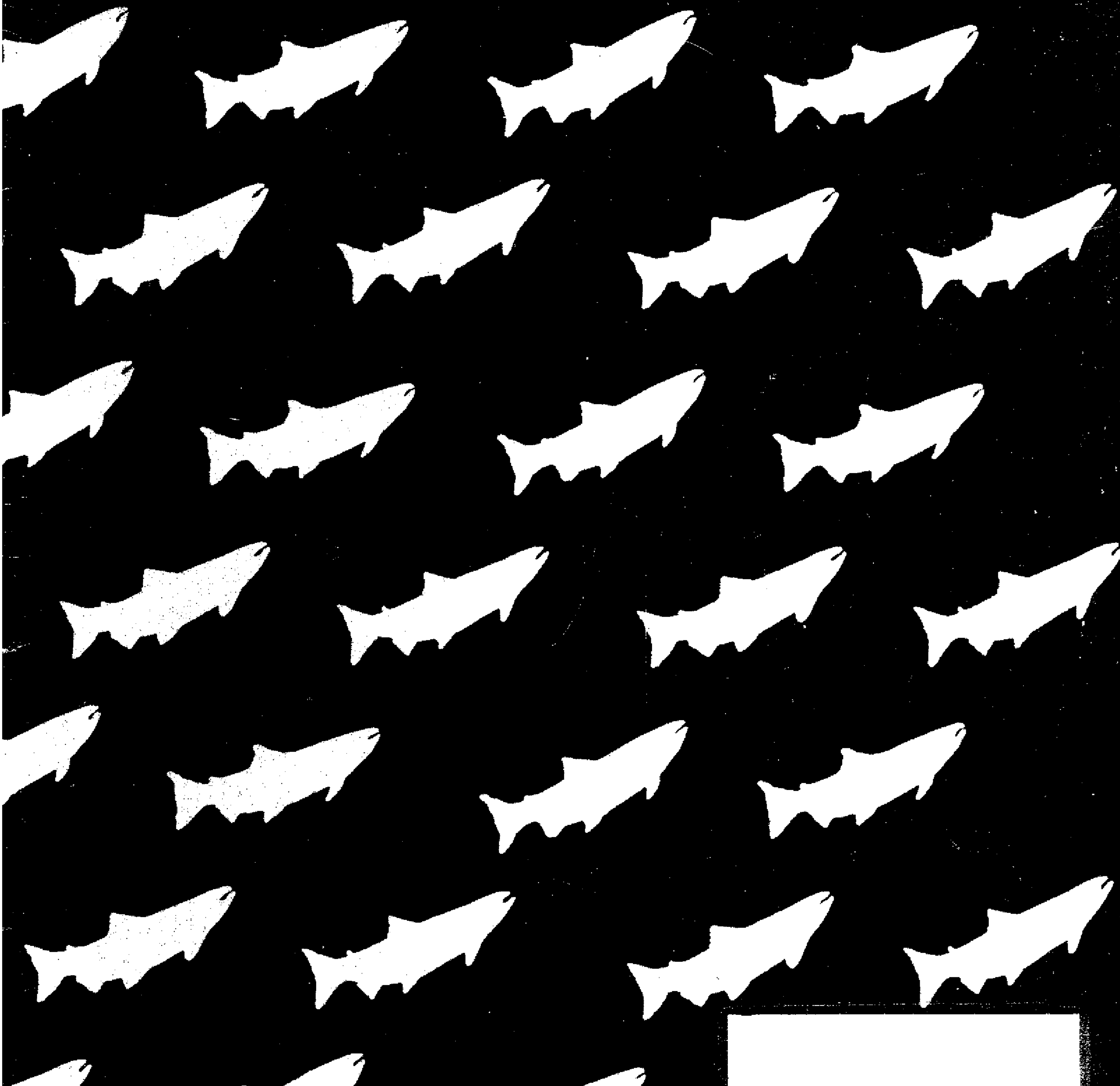

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INTRODUCTION

Atlantic salmon is an important resource for both commercial and sport fishing along the Atlantic coast of Canada. Unfortunately, overfishing has severely depleted the stock and commercial fishing has been very limited. Consequently the debate over resource allocation among different user groups has intensified. At the same time increasing demand and dwindling supply have resulted in higher prices and have fostered strong interest in Atlantic salmon farming.

A demand analysis for Atlantic salmon can provide useful information for exploring the market potential for farmed salmon in Canada. The importance of integrating demand function into economic analysis of fishery management has been demonstrated (Blomo et al. 1982, Kellog et al. 1985, Bell 1986). Therefore, a better understanding of the demand for Atlantic salmon will facilitate the development and implementation of management schemes for Atlantic salmon.

Kabir and Ridler (1984) hypothesized that per capita domestic consumption, real per capita disposable income, and real price of meat or poultry are the determinants of the real price of Atlantic salmon. Their empirical results suggest that the lower bounds of demand own-price elasticities are high, ranging from 8.33 to 14.28, dependent on the product form (fresh or fresh and frozen) and model specification. Atlantic salmon was found to be a luxury good with income elasticities ranging from 3.25 to 5.62. The price of meat or poultry was found to be unimportant in determining the price of salmon. In a 1985 paper they reported that lobster is a closer substitute for salmon than meat or poultry.

This study extends the work of Kabir and Ridler in two ways. First, the effect of functional form selection on parameter estimates is examined. Different functional forms will result in different elasticity estimates and different measures of consumer surplus (Zeimer et al. 1980). The log-log functional form chosen by Kabir and Ridler is known for producing constant elasticities. This functional form is tested by using the extended Box-Cox flexible functional form. Second, because the annual data used span a long period the stability of parameter estimates is examined. If parameter estimates obtained from a particular functional form are not stable during the sample period, the empirical results become meaningless.

THE MODEL

As shown in equation (1), the single equation model specified in this study follows the work by Kabir and Ridler with minor modifications.

$$(1)\ P = f(Q, PL, FY)$$

Real per capita expenditures on food (FY) rather than real per capita disposable income is used as one of the demand shifters. This change is motivated by the concept of the weakly separable utility function in consumption economics. Correspondingly, the consumer price index for food is used to derive real monetary variables. Real price of lobster (PL) and domestic per capita consumption of fresh and frozen Atlantic salmon (Q) are also expected to influence the real price of Atlantic salmon (P). It is expected that FY and PL have positive effects on P, and Q has a negative impact on P. The price-dependent model is specified because landings of Atlantic salmon are mainly affected by environmental, biological, and regulatory factors but not by prices. The single-equation model can be justified under the assumption that exports of Atlantic salmon are exogenously determined. This assumption is retained here because the use of the Box-Cox flexible functional form and the test of parameter stability are yet to be developed for simultaneous-equation models.

EMPIRICAL RESULTS

This study added 1982 data to the 1955 through 1981 annual data used by Kabir and Ridler. Data were collected from various publications of the Canadian government. Food expenditures, population, and the consumer price index for food are published by Agriculture Canada. Quantity and price of fresh and frozen Atlantic salmon and price of lobster are available from Statistics Canada. Exports of fresh and frozen Atlantic salmon are published by the Canadian Bureau of Statistics. All of the variables are first converted into indices with their 1982 values being set at 1 and then scaled by their respective geometric means.[1]

Log-Log Functional Form

Since the model is different from the one specified by Kabir and Ridler, the log-log functional form was reestimated with the following results.

$$(2)\ \ln P = -0.000003 - 0.1 \ln Q + 0.52 \ln PL + 1.1 \ln FY$$
$$\quad (0.0002) \quad (2.4) \quad (5.6) \quad (7.7)$$

$R^2 = 0.80$, Adj. $R^2 = 0.77$, DW $= 1.82$, LLF $= 36.39$, SSE $= 0.12$

The numbers in parentheses are t statistics in absolute values; LLF is the value of log-likelihood function; and SSE is the sum of squared errors.

Judging from the signs of parameter estimates, R^2, t statistics, and DW statistic, the log-log functional form appears to produce satisfactory results. By rearranging equation (2), the lower limit of the demand own-price, cross-price, and income elasticities are 10, 5.2, and 11.95, respectively. As will be discussed later, the log-log functional form does not perform as well as the Box-Cox functional form. Therefore, above results are not interpreted here.

Box-Cox Flexible Functional Form

Since the selection of functional form is an important econometric issue, the monotonic transformation introduced by Box and Cox in 1964 has become a popular tool for both discriminating among alternative functional forms and providing added flexibility in model specification (Moschini and Meilke 1984).

[1] As discussed by Spitzer (1984), scaling variables (at least for the dependent variable) by their respective geometric means will reduce the extent of over- and under-estimation of t statistics in estimating the Box-Cox functional form. The geometric means of P, Q, PL, and FY are 1.438, 1.92, 1.259, and 1.212, respectively.

The Box-Cox functional form as extended by Zarembka (1974) for a regression model in a matrix form can be expressed as

(3) $Y^{(\lambda)} = X^{(\mu)}\beta + \varepsilon$

where

$$Y^{(\lambda)} = \begin{cases} (Y^{\lambda}-1)/\lambda & \text{if } \lambda \neq 0 \\ \ln Y & \text{if } \lambda = 0 \end{cases}$$

$$X^{(\mu)} = \begin{cases} (X^{\mu}-1)/\mu & \text{if } \mu \neq 0 \\ \ln X & \text{if } \mu = 0 \end{cases}$$

and β, λ, and μ are parameters and ε is the error term.

The extended Box-Cox flexible functional form includes the linear ($\lambda = \mu = 1$), log-log ($\lambda = \mu = 0$), log-linear ($\lambda = 0$ and $\mu = 1$) and other specifications as special cases and does not impose any restrictions on the demand price and income elasticities (Gemmill 1980). Parameters β, λ, and μ can be estimated by maximum likelihood estimators (Spitzer 1982). The Box-Cox flexible functional form was estimated by using the SHAZAM package (White 1978). Results are summarized as follows:

(4) $P^{(0.58)} = 0.05 - 0.08Q^{(1.9783)} + 0.34PL^{(2.1931)} + 0.68FY^{(-8.1058)}$
(3.67)(2.61) (4.40) (9.15)

$R^2 = 0.83$, Adj. $R^2 = 0.82$, DW = 2.1, LLF = 40.82, SSE = 0.089

Judging from t statistics and R^2, the Box-Cox functional form appears to fit the demand function better than the log-log functional form. The signs of parameter estimates are also consistent with a priori theoretical expectations. By comparing the values of the log-likelihood function in (2) and (4) in a χ^2 distribution with the degrees of freedom equal to the number of powers in the

Box-Cox functional form (i.e., 4), the log-log functional form can be rejected at a 6.5 percent probability level.[2]

Because all of the variables in the model are divided by their geometric means, the coefficients in equation (4) can be used to calculate elasticities at geometric means (Spitzer 1984). The lower bound of the demand price elasticity (i.e., the reciprocal of the coefficient of Q) is 12.5 and the cross price and income elasticities are 4.2 and 8.3, respectively. These elasticities differ from those of the log-log functional form by 20 percent or more. Furthermore, the curvature of the Box-Cox functional form is different from that of the log-log functional form, implying that the these two functional forms will produce different welfare measures.

The high demand price elasticity for Atlantic salmon implies that fishermen's revenues can be increased substantially by successful salmon stock enhancement programs. In addition, increases in the supply of farmed Atlantic salmon have a small impact on the price of Atlantic salmon, provided that wild and farmed salmon have similar demand characteristics. Therefore, market potential for farmed Atlantic salmon appears to be good. Of course, it is still necessary to examine whether wild and farmed salmon are perceived by consumers to be similar products. Due to data limitation, market surveys seem to be a better approach than the regression method in addressing this issue.

The high cross price elasticity suggests that lobster and Atlantic salmon are close substitutes. Finally, the finding of high income elasticity, which is about twice the magnitude reported by Kabir and Ridler, suggests that Atlantic salmon is a luxury good. The high income elasticity also implies that fishermen's income will fluctuate to a greater extent than swings in the economy. This is an important consideration for those salmon farmers who are risk averters and/or have tight financial constraints.

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[2]The powers used to transform PL and FY in this Box-Cox functional form are 2.1931 and -8.1058, repectively. This finding raises concern over use of the iterated ordinary least squares method which usually searches within the range of (2,-2) for each power transformation for maximizing the concentrated log-likelihood function. In other words, the iterated ordinary least squares method may find the local optimum rather than the global optimum.

Parameter Stability

Even though the Box-Cox functional form appears to fit the demand function for Atlantic salmon better than other functional forms, its results can be misleading if parameters are not stable. Since annual data from a long period (1955 through 1982) are used in this study, it is necessary to detect any occurrence of structural changes.

The Farley and Hinich, CUMSUM, and CUMSUM-square tests are used to test parameter stability in this study. Farley and Hinich (1970) suggest that a discrete shift in parameters due to structural changes be approximated by a linear trend process. Approximation is needed because the timing of structural changes is usually unknown. To be specific, a time varying parameter α_t is to be approximated by $\alpha + t\beta$. The Farley-Hinich test involves testing the null hypothesis that $\beta = 0$ against the alternative hypothesis that $\beta \neq 0$. The test may involve the full set or only a subset of parameters. When more than one parameter is tested for stability, the joint hypothesis testing procedure should be followed.

Table 1 summarizes some of the results for both log-log and Box-Cox functional forms using the Farley-Hinich procedure. Empirical evidence strongly indicates that the parameters of the log-log functional form are unstable while those of the Box-Cox functional form are stable.[3]

The CUMSUM and CUMSUM-square procedure, developed by Brown et al. (1975), tests parameter stability by using recursive residuals. Excellent discussion of recursive residuals and these two tests can be found in Johnston (1985). The CUMSUM test primarily detects systematic movements in the coefficients and the CUMSUM-square test detects haphazard movements in the

[3]To further support this statement, regression results of testing the parameter stability of the quantity variable for the log-log functional form are reported here.

$$P = 0.02 - 0.37Q + 0.01Q^{*}t + 0.5PL + 1.1FY$$

(1.54) (3.5) (2.7) (6.1) (8.8)

Table 1. Results of Farley-Hinich Test.

Parameters tested	SSE	F-statistic	Degrees of freedom
		Log-log functional form	
Q, PL, & FY	0.069	5.33	(3,21)[a]
Q	0.092	7.50	(1,23)[b]
PL	0.091	7.84	(1,23)
FY	0.098	5.67	(1,23)
		Box-Cox functional form	
Q, PL, & FY	0.070	1.90	(3,21)[a]
Q	0.830	1.55	(1,23)[b]
PL	0.080	2.50	(1,23)
FY	0.089	0.05	(1,23)

[a] Critical F value is 3.97 at a 5 percent probability level.

[b] Critical F value is 4.28 at a 5 percent probability level.

coefficients. The CUMSUM test plots a quantity W_t constructed from recursive residuals and the CUMSUM-square test plots another quantity denoted by S_t which is constructed from W_t. Under the null hypothesis of no parameter instability, the probability bounds for both W_t and S_t can be determined. The null hypothesis will be rejected if the plot crosses the boundaries associated with the chosen probability level.

The Box-Cox functional form is further examined for parameter instability by using the CUMSUM and CUMSUM-square plots. Results of these two tests are shown in Figures 1 and 2. These two tests again suggest that the Box-Cox functional form for estimating the Canadian demand for Atlantic salmon is satisfactory.

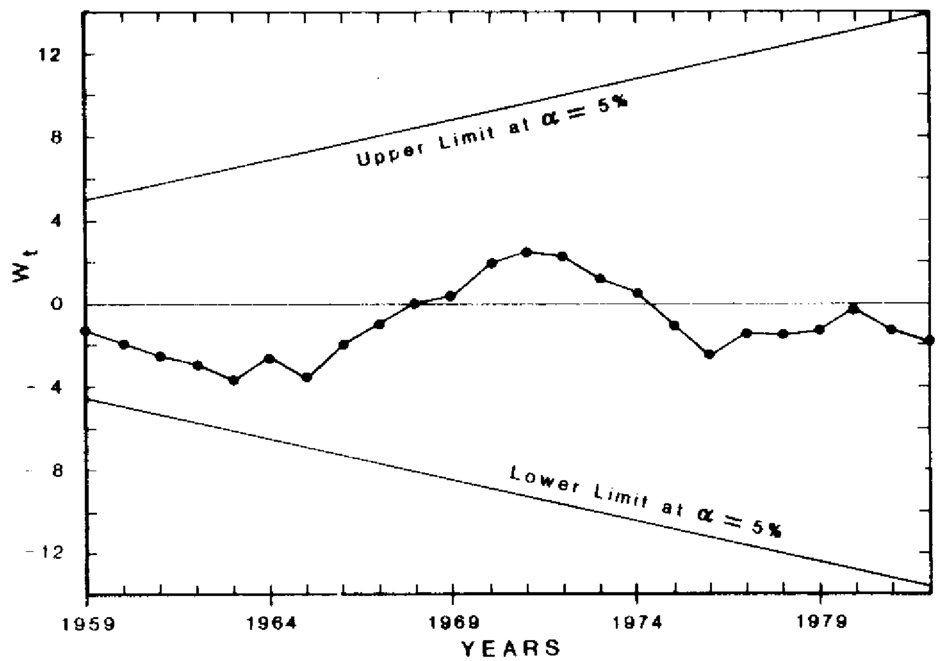

Figure 1. Results of CUMSUM test for parameter instability.

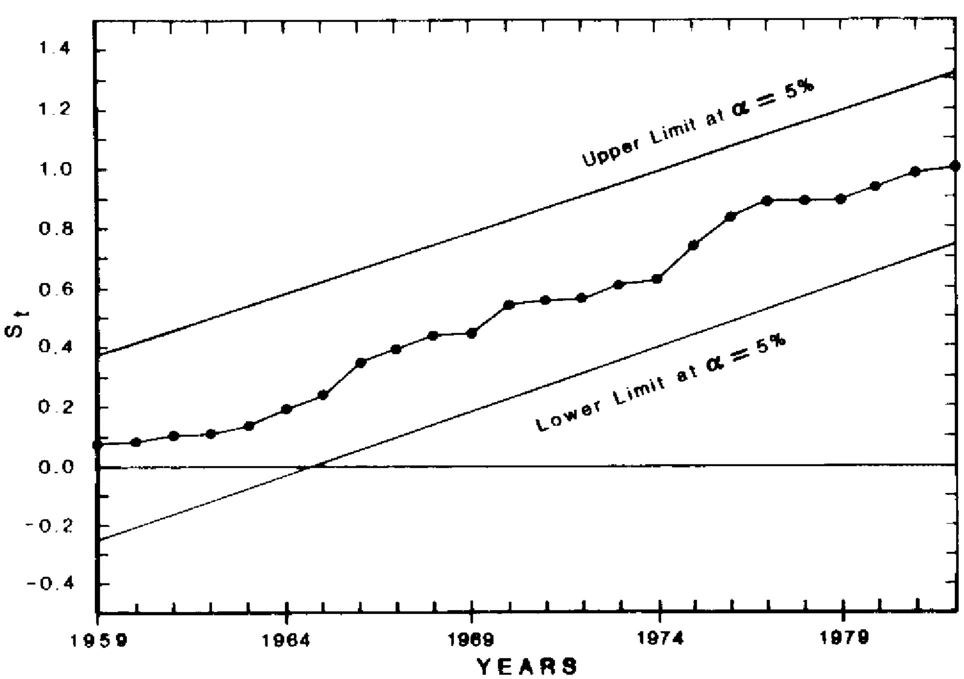

Figure 2. Results of CUMSUM-square test for parameter instability.

SUMMARY

This study extends Kabir and Ridler's work on the demand for Atlantic salmon in Canada by examining the importance of selection of functional forms and testing of parameter stability. The Box-Cox flexible functional form is found to perform better than the log-log functional form. Further, the Box-Cox functional form produces stable parameter estimates whereas the log-log functional form does not.

Evaluated at geometric means, the demand own-price, cross-price, and income elasticities for Atlantic salmon in Canada are found to be 12.5, 4.2, and 8.3, respectively. The high demand own-price elasticity suggests that successful salmon stock enhancement programs can increase fishermen's revenues substantially. It also implies that there is great potential for the growth of the farmed Atlantic salmon industry, provided that wild and farmed salmon have similar demand characteristics. The high cross-price elasticity indicates that lobster and Atlantic salmon are good substitutes. The income elasticity suggests that Atlantic salmon is a luxury good. This high income elasticity is important for salmon farmers who are risk averters and/or have tight financial constraints, because it implies that sales will fluctuate to a greater extent than swings in the economy.

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