The US salmon market : demand characteristics and price linkage

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Summary

In this paper, we study the short run price dynamics of imported fresh, farmed Atlantic and Pacific salmon on US regional markets. An Error Correction framework is used to specify a short run model. The results show a substitute relationship among the different salmon species in that an adjustment process corrects for disequilibrium errors (i.e. deviations from the long run equilibrium). However, in the short run, individual prices show substantial independence in price variation.

Keywords: Salmon Markets, Prices, Short Run Dynamics

I. Introduction

The United States is the largest salmon market in terms of both demand and production. Production of salmon includes both wild harvests (Pacific species), as well as farmed salmon (Atlantic, chinook *and* coho). In addition, there are large quantities of imported farmed and wild salmon species on the US market. During the 1980's, the price of salmon maintained a relatively high level as demand increased to keep pace with increased production and imports of salmon. By the end of the 1980s, the continuing growth in the supply or salmon (primarily farmed Atlantic) surpassed the growth in demand for the commodity. The market response was a 33% decline in the price of Atlantic salmon and approximately a 19% decline in the price of high valued Pacific salmon over the period 1988-89.

The growth in supply was realized through technological advances and disease control in the production of farmed fish. What is more, these developments allowed for a continuous supply of salmon throughout the year. Norway introduced farmed salmon to European and US markets, but US production expanded rapidly and over the period 1981-91 increased from 500 to 7,600 tonnes1[1]. Farmed Atlantic salmon is considered a high-valued fish as are the Pacific species chinook, sockeye and coho. It would seem reasonable to consider Atlantic and high-valued Pacific species substitute commodities in the consumer demand set. Certainly, a number of studies have measured a substitute relationship between Atlantic and high-valued Pacific species but the results are inconsistent (see Gordon, 1985; Rogness and Lin, 1986; Lin and Herrmann, 1987; Hermann and Lin, 1988; Lin et al., 1989; Hermann, 1990; Mittelhammer, Herrmann and Lin, 1990; Hermann,

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1[1] US Department of Commerce, National Marine Fisheries Service, various years.

Mittelhammer and Lin, 1993; DeVorets and Salvanes, 1993). Moreover, within the industry salmon is not considered a homogeneous product and there are widely held views as to the degree of substitutability, which may exist among the various species. Buyers of salmon grade on method and location of catch, species, product form, quality, color, season and size. The importance of each characteristic depends on the buyer and the market level for which the product is purchased. Certainly, a necessarily condition for substitutability is the availability (or at least the potential availability) of alternative species on a well-defined market.

The purpose of this study is two-fold: First, to present an overview of the main characteristics of the US salmon market delineated by Atlantic and high-valued Pacific species:

Second, to attempt to measure the short-run price relationship between Atlantic and high-valued Pacific salmon species within an equilibrium context. The data set collected by the US National Marine Fisheries Service (NMFS) represents monthly import price data differentiated by species and product form for the period 1989-1993. It is possible that the desegregated data will allow for improved measurement of the price relationship among different salmon species relative to the aggregate data used in previous studies. The empirical study will be limited to fresh, farmed imported salmon and will include Atlantic salmon and the high-valued chinook and coho species of Pacific Salmon. Price linkages among the commodities should be of interest to both fish farmers and fishers. The stochastic nature of the wild catch introduces uncertainty as to price and availability and, in the absence of demand response, the increasing supply of farmed Atlantic salmon will continue to put downward pressure on salmon prices.

II. Supply and Demand Characteristics: Us Salmon Market

A natural starting point in investigating the price relationship among the different salmon species is an examination of the markets in which the fish are sold. On the supply side, the US is a large harvester of wild salmon accounting for roughly 45% of world catch (Bjorndal, 1990). The primary fishing grounds are off the coast of Alaska, Washington and Oregon. The harvest varies considerably from year to year and among species. Although the yearly share in total catch of the different species is relatively stable, in Table l, we report the Pacific harvest by species for the period 1987-1992 with relative shares in parentheses (NMFS, various years). The annual capture of Pacific salmon averaged 316.5 thousand tonnes over this period.

The annual harvest of farmed salmon in the US is substantially less than the wild catch at roughly 8,000 tonnes in the early 1990s2[2]. Atlantic salmon accounts for 70% of the farmed harvest and fish farming occurs primarily on the East Coast of the US. West Coast salmon farms produce chinook, coho and small amounts of the Atlantic variety. Farmed fish are targeted primarily for the high priced fresh market.

The domestic supply of salmon is augmented by large quantities of imported salmon primarily from Canada, Chile and Norway. Over the five-year period 1988-92, total imports of all species of salmon reached 50 million tonnes and represents about a 40% annual share of the domestic market. The majority of imports is fresh

2[2] Unless otherwise noted, all figures are estimates based on US trade statistics compiled by the national Marine Fisheries Service. Domestic aquaculture production figures are from Anderson and Bettencourt, 1992.

salmon (87%) with small amounts of frozen (10%), smoked (2%) and canned (1%) product forms. Of the fresh imports, the largest volume is made up of farmed Atlantic salmon but, in the early 1990s, imports of high valued Pacific salmon (chinook, coho and sockeye) accounted for 40% of the market.

Prior to 1990, Norway was the dominant producer and supplier of farmed Atlantic salmon accounting for over 50% of total imports. Figure 1 shows the changing market share of the major suppliers of fanned Atlantic salmon over the period 1989-93. Norway's market share virtually disappeared with the introduction by US in April 1991 of anti-dumping duties against fresh, fanned Atlantic salmon from that country. Both Canada and Chile were quick to respond to the demise of Norwegian supply and by 1993, held market shares of 48% and 46%, respectively. Other importers include Iceland, Faroe Islands and UK.

Imports of high valued Pacific salmon originate from Canada and to a lesser extent from Chile. Canadian supplies of farmed and wild chinook and coho account for over 95% and 90%, respectively of total fresh imports of these species.
The main regional centers for trade in salmon are Seattle and Portland on the West Coast and Boston, New York and Miami on the East Coast. San Francisco and Los Angeles also play a role in marketing fresh salmon but to a much lesser extent. The US wild Pacific catch is directed mainly through Seattle and Portland, whereas, US farmed Atlantic salmon is directed through Boston.

In 1991, the domestic supply of Chinook salmon reached nearly 20 thousand tonnes of which approximately 65% were imported from Canada, and of that, roughly half was farmed. The Seattle market handles all imports of tins species. The total supply of coho salmon is dominated by domestic production with imports accounting for only 17% of the market. Of the imports, 90% originate from Canada. Coho salmon is farmed in Washington and Oregon as well as in British Columbia, and to a lesser extent in Chile. Again, Seattle is the major market for imported fresh coho salmon. However, Chilean supplies are marketed through Miami and New York.

Imports of Atlantic salmon are handled in all regional markets. Canadian supplies are marketed through Seattle and Portland. Moreover, the Seattle and Portland markets combined account for 44% of the total amount of Atlantic salmon imported in the US in 1991. The East Coast is primarily supplied by Chile with smaller amounts coming from Iceland, Faroe Islands and UK. The markets in New York and Miami handle respectively 24% and 22% of total imports of fresh Atlantic salmon. For this species, Chile is the dominant supplier in both markets accounting for some 92% of the Miami market and 56% of the New York market. The market in New York is also supplied by Scotland, Iceland, Norway3[3] and Faroe Islands. Figure 2 summaries the distribution of imported, fresh Atlantic salmon among the regional markets over the period 1989-1993.

The various species, which dominate the fresh salmon market, have distinguishable distribution patterns, separated primarily on a geographical basis. As is shown in Figure 3, Atlantic salmon is sold primarily on the East Coast while Pacific salmon is concentrated in the west. The demand preferences of intermediate fish buyers also appear distinguishable on a geographical basis. Anderson and Bettencourt (1992) found that buyers' choice is influenced by the attributes of the product: species, origin, catch method, availability, color, freshness, quality and form. The ordering of these attributes varied between the

3[3] Prior to 1991.

two regions yet both ranked quality, product form, freshness and origin highly. In the Northeast, Atlantic salmon was preferred to the Pacific varieties of chinook and coho. Restaurants in the eastern US showed a preference for Norwegian salmon. On the West Coast, Pacific varieties were clearly preferred to Atlantic.4[4]

It has been common in empirical analysis of salmon markets to take a direct approach in modelling and estimating demand functions (either structural or reduced form). A substitute relationship is measured by the estimated price coefficient associated with Atlantic salmon in the demand function for Pacific salmon, or conversely. The purpose of such studies is to measure the price and income characteristics of the demand function and to predict the impact of farmed fish on the salmon market. Lin and Hermann (1987) appear to be the first to make a serious attempt at measuring the relationship between farmed and wild salmon species and many studies have since appeared. Herrmann (1990) constructed an international model with the price of substitutes within the salmon demand equation endogenous. The paper reported a strong substitute relationship among high valued Pacific salmon, Chilean imports and Norwegian Atlantic salmon.

The results by DeVoretz and Salvanes (1993) for both European and US salmon markets are consistent with the earlier studies, albeit showing a greater range in the magnitude of estimated coefficients. Table 2 provides a summary of elasticity estimates reported in a number of studies of the salmon market. All studies except Lin et al. (1989) report a substitute relationship (in some cases a weak relationship) between Atlantic and Pacific species of salmon5[5].

4[4] Herrrmann, Lin and Mittelhammer (1990) provide survey results of buyers' preferences over different species and product forms.

5[5] Regardless of these results, it is interesting to note that the US International Trade Commission (April, 1990) ruled that fresh, farmed Atlantic salmon did not share a substitute relationship with Pacific salmon!

Table 2 : A Summary of Elasticity Estimates: US Salmon Market

Papers	Years Studied	Species included	Income elasticity	Own-price elasticity	Cross-price elasticity
Lin & Herrmann 1987	1983-1986	Atlantic *Chinook*	3.6 -7.12	-1.44 (-2.48)	0,11 (0,27)
Herrmann & Lin 1988	1983-1987	Atlantic *Chinook*	4.51	-1,97	0.56
Lin et al. 1989	1983-1987	Atlantic *Chinook*	2.3	-1.92	0.17*
DeVoretz & Salvanes 1993	1983-1988	Atlantic *Chinook* *Coho*	0.05	-5.64	1.15
Herrmann. Mittelhammer& Lin 1993	1983-1988	Atlantic *Chinook.* *Coho* *Sockeye*	3.28 -5.3	-1.35 (-2.18)	0.45 -0.72

Long-run estimates in parentheses
*indicates atistically insignificant at the 0% level

An alternative empirical approach is to apply time series techniques to define the parameters of the market6[6]. These techniques require the researcher to investigate and measure the characteristics of the data generating process. This work was developed by Granger and Newbold (1974) and Granger (1986) and has since been widely used empirically to study price relationships and market analysis (Gordon, Salvanes and Atkins, 1993 ; Asche, Salvanes and Steen, 1994 ; Vukina and Anderson, 1994).

If the data generating process results in a series with moments (mean variance and covariance) invariable with respect to time, the series is defined as a stationary process. Economic variables generally require differencing (d) one or more times before the stationarity property is achieved. Such a series is defined as integrated of order d. Traditional demand analysis which fails to properly account for the integrated process can lead to spurious regression results (Holden, Peel and Thompson, 1990). Time series techniques allow both for an investigation of the long run relationships among a defined set of co integrated variables and of the short run dynamic characteristics using an error correction model. Granger (1986) has shown that a co-integrated system implies the existence of a short run error correction model and conversely.

Our empirical approach is to delineate the price linkages among the different species of high-valued salmon in regional US markets using short-run time series techniques, which incorporate the long run equilibrium relationship.

III. Modelling Price Linkage

In the short run, it is likely that the price variables of interest will deviate substantially (say, due to stochastic supply and demand shocks) from a given reference point, but if prices are part of a stable equilibrium system, then eventually such deviations must revert to the reference point (Engle and Granger; 1987). In the Granger sense, it is this notion of long run equilibrium on which a short run dynamic model is formulated. Specifically, in the short run, two adjustments are allowed for; first, is that prices can adjust to shocks slowly and with a lagged effect (i.e., the substitution from one product to another is not immediate), and second, is that the system itself must adjust to deviations from the long run equilibrium path (i.e., disequilibrium from one period is corrected in the next). So, in essence, the short run model relates the change in the variable of interest to past equilibrium errors as well as to past changes in the price variables that define the model.

Following Granger (1986), the short-run Error Correction Model (ECM) can be written in a general form as:

$$\Delta P_{it} = -\varrho Z_{it-1} + lagged\,(\Delta P_{it}, \Delta P_{jt}) + \epsilon_{it} \qquad (1)$$

where ΔP_{it} is the change in price i period t, Z_{it-1} is the long run equilibrium adjustment factor with the ϱ adjustment coefficient and ϵ_{it} is the random error term. In equation (1), we are working with the change in price so long run effects are purged from the variables. The change in price variables capture short run shocks to the model and lagged values allow for adjustment to occur overtime. Z_{it-1} forces the short run model to maintain the long run equilibrium, where deviations from the equilibrium are corrected in subsequent periods.

If equation (1) is a proper and consistent representation of short run dynamics, the change in price variables must each be a stationary series and, what is more, Z

6[6] See, Dickey, Jansen and Thornton. 1991 and Charemza and Deadman, 1992 for a discussion of time series modelling.

must also be stationary. Granger (1986) has shown that for a proper and consistent ECM to exist the variables of interest must define a long run equilibrium relationship (i.e., the variables must be co-integrated). Granger's specification allows the equilibrium to enter the model through the inclusion of Z_{it-1}, but does not constrain the model to satisfy equilibrium. This contrasts to models, which impose equilibrium restrictions and is preferable in that equilibrium is a testable hypothesis rather than imposed (Engle and Granger, 1987).

Our estimation procedure is straightforward. First, we estimate an auxiliary regression of the levels of each price series on past values of the price variables of interest. If a long run equilibrium exists, the regressions in the levels of the prices represents a co-integrated system and the predicted errors from such a regression can be defined as the equilibrium adjustment factor, Z_{i}. These values are then used in the primary regression, equation (1).

The data used in estimation are obtained from the US Department of Commerce, National Marine Fisheries Service. The data represent monthly import values and quantities (metric tonnes) of salmon according to species and product form.7[7] A suitable transformation of value and quantity defines prices for farmed Atlantic, chinook and coho salmon, by supplier and by regional market.8[8] The price series represent wholesale values. It was decided to use only fresh farmed salmon for the three species chosen because the supply of farmed reared salmon is consistent both in quality and in timing on the market. In Table 3, the price variables are defined by species, supplier and regional market.

7[7] Product is differentiated by fresh, frozen, smoked and other processed forms.

8[8] While there are five commercially important species of salmon, the US market for fresh salmon is dominated by Atlantic, chinook and coho. These species account for over 82% of the total US imports of fresh salmon and over 93% of high-valued fresh salmon imports.

Table 3. Price Variable Definitions

Variable	Species	Supplying Country	Sub-Market
ASCS	Atlantic	Canada	Seattle
ASCLA	Atlantic	Canada	Los Angeles
ASCSF	Atlantic	Canada	San Franctsco
ASCHNY	Atlantic	Chile	New York
ASCHLA	Atlantic	Chile	Los Angeles
ASCHM	Atlantic	Chile	Miami
ASINY	Atlantic	Iceland	New York
ASFINY	Atlantic	Faroe Islands	New York
ASUKNY	Atlantic	United Kingdom	New York
CHCS	Chinook	Canada	Seattle
COCS	Coho	Canada	Seattle

We provide a summary of the price data in two ways. First, in Figure 4, we show the price of different salmon species in different markets. There are a number of points to the figure. In the top chart, price variation across species is substantial. Atlantic salmon fetch the highest price, then chinook, then coho. Although there are some obvious deviations in prices, they tend to move together over the time-period 1989 to 1993. The middle chart shows Atlantic prices of the different import suppliers on the New York market. These prices trend closely together but UK suppliers appear to have benefited somewhat from higher than average prices relative to others in January 1989 and again in July 1993. The bottom chart shows Chilean Atlantic salmon prices in three sub-markets: New York, Miami and Los Angeles. Again, subject to some individual variation, the prices appear to follow a similar trend across sub-markets for the same species.

Second, we report a summary statistic used to test the stationarity properties of individual prices. In estimating equation (1), our interest is to determine if the change in each price variable is stationary. It is common in this literature to define stationarity using an Augmented Dickey-Fuller (ADF) statistic. For our purposes, the appropriate null hypothesis is that each price series is stationary after differencing twice against the alternative hypothesis of stationary after differencing only once. The summary statistic is generated from a regression equation of the form:

$$\Delta P_{it,} = \alpha_0 + \varphi P_{it-} + \alpha_\tau Time + \sum \alpha_s \Delta P_{it-s} + \vartheta_{it} \qquad (2)$$

The length of the lag, s, is set to capture correlation within the model and obtain white noise in the error term, in. The summary statistic of interest is the ratio of the estimated value of *(p)* to its standard error.9[9] This statistic is sensitive to lag length chosen and we follow Gordon (1995) and evaluate the statistic at different lagged values, 1 through 12.

In Table 4 we report the ADF statistic generated at lag 1 and 5 for each of the transformed price series10[10]. To reject the null hypothesis and not reject the alternative (i.e. stationary after differencing once) requires a calculated statistic smaller then –3.13 at the 10% level (Dickey and Fuller, 1979). These results are obtained for all price series except Atlantic salmon from Iceland in the New York market (ACINY) at lag 5. For this variable, evaluating the calculated ADF at each lag shows that the null can be rejected only at lag lengths less than 4. With this in mind, we proceed based on the conclusion that each price series is stationary in first differences.

9[9] to test the null hypothesis each series is differentiated once and then the transformation is again differentiated prior to estimating equation (2).

10[10] The ADF test was also used to test the null hypothesis that each price series is stationary in first differences against the alternative of stationary in levels. The results were ambiguous.In some cases, not rejecting the null at each lag lengh exaamined but, in other cases, oscllating between rejection and non-rejection depending on lag lengh chosen. We read the inconsistency in results as indicating non-stationarity in the levels of each series.

Table 4 Summary Statistics ADF: Stationarity

Variable*	Lag 1	Lag 5	Decision**
ASCS	-6.2	-5.2	Reject
ASCLA	-8.4	-4.9	Reject
ASCSF	-7,8	-5	Reject
ASCHNY	-5,1	-4.1	Reject
ASCHLA	-8.1	-3,2	Reject
ASCHM	-9	-4.7	Reject
ASINY	-7.9	-3	Do Not Reject
ASFINY	-8.9	-5.1	Reject
ASUKNY	-7.9	-4,8	Reject
CHCS	-7.5	-3.3	Reject
COCS	-9.1	-5.3	Reject

*Each variable represents the change in price.

**The null hypothesis is that each price variable is stationary in second differences against the alternative of stationary in first differences. Critical value at the 10% level is -3.13.

In estimation of equation (1), the regional markets are separated on an east/west geographical division; New York and Miami on the East Coast and Seattle, San Francisco and Los Angeles on the West Coast. Within each geographical division prices are defined by salmon species and by country of import. On the East Coast, Atlantic salmon prices are defined for Chile, Iceland, Faroe Islands and United Kingdom. The price series for Pacific species from Chile on these regional markets is not complete and as a proxy we use the price of Canadian chinook and coho on the Seattle market. On the West Coast, Atlantic salmon prices are defined for Canada and Chile. Canadian chinook and coho Pacific species are also available.

The first step in estimating equation (1) is to set up and estimate an auxiliary regression for each geographical market where one price is regressed on the lagged values of all other prices in the defined market. All prices are in level form. As price endogenaity is not clearly defined, the procedure is repeated for each price variable. Specifically, for each price variable the following regression equation is estimated:

$$P_{it} = \beta_0 + \sum^m{}_j \beta P_{it} + v, \qquad i \neq j \qquad (3)$$

A number of different specifications of equation (3) were attempted in the empirical search for a 'reasonable' model. A time trend was included, as were dummy variables to account for the possibility of seasonality and the impact of Norwegian supplies being forced from the market in 1991. The goal is to obtain predicted residuals from each regression that satisfy stationarity. Consequently, a reasonable model is one identified by stationary errors. Without too much difficulty, we were able to obtain such errors for all regressions of equation (3), except when the Canadian price of coho salmon and again when the Icelandic price of Atlantic salmon were defined as the endogenous dependent variable. This may indicate that a proper short run price model does not exist for these variables in the markets defined, and we exclude them from further analyze. For the remaining equations the predicted errors are saved, lagged one period and combined with the first difference of each price series to allow us to proceed with estimation of equation (1).

In each region and for each price variable, we estimate an ECM as defined in equation (1). The specification of each regression is ad hoc, but we are guided in lag formation using a minimum Akaike Information Criteria (AIC)11[11]. We report the results of the final specification of each equation in Table 5 and 6 for the West and East Coast, respectively.

For each estimated equation, the equilibrium adjustment factor, Z (which maintains the long run equilibrium within the short run model), is negative and statistically significant at greater than the ten percent level. This can be interpreted to mean that individual prices can not diverge too far before some type of arbitrage forces a return to the equilibrium. The size of the estimated adjustment coefficient is a measure of the distance (shock) away from the equilibrium (Holden, Peel and

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11[11] The AIC is defined as: $AIC = n{*}ln(RSS/n) + 2{*}k$ where k is the number of estimated parameters, n is the number of observations and RSS is the residual sum of squares.

Thompson, 1990). In a more generous interpretation, this means that the Atlantic and Pacific salmon species investigated here are part of the same market segment and represent substitute commodities within the general price system.

The short run dynamics in the model which are measured by individual price effects tells a somewhat different story. For some equations, the price interaction among the different species is nonexistent. By this, we mean that only own past price effects influence or determine current price changes, e.g., equation 1 (Atlantic salmon from Canada on the Settle market, ASCS) and equation 3 (Atlantic salmon from Canada on the San Francisco market, ASCSF) in Table 5 and equation 2 (Atlantic salmon from Chile on the Miami market, ASCHM) in table 6. In other words, short run price formation of these commodities is independent of price changes of other salmon commodities. Such prices are not constrained in the short run to respond to price shocks from other salmon species even though they are constrained within the larger price system. However, for other equations the response to short run price shocks in other salmon prices is substantial. Atlantic salmon from Canada on the Los Angeles market (ASCLA, equation 2, Table 5) responds well to price shocks from other Atlantic and Pacific species, as does Atlantic salmon from Faroe Island on the New York market (ASFINY, equation 3, table 6). In these two equations, we measure substantial interaction among the different products and species.

Table 6 : Error Correction Models Pacific and Atlantic Salmon East Coast Markets

	Dependent Variable				
Independent Variables	Δ ASCHNY	Δ ASCHM	Δ ASFINY	ΔASUKNY	Δ CHCS
Z_{t-l}	0.647 (-4.$_7$67)[a]	0.397 (-3.019)	*0.659* (-.586)	0.802 (-5.942)	0.45 (-3.811)
Δ *ASCHNY*					
Δ *ASCHM*					
Δ *ASINY*	*0.291* *-3.118*		*0.335* *-2.01*		*0.122* *-1.345*
Δ *ASFINY*					
Δ *ASUKNY*			*0.165* *-2.431*		
Δ *CHCS*			*0.383* *-1.515*		
Δ *COCS*	*0.066* *-1.422*		*-0.114* *(-1.373)*		
Δ *ASCHNY* $_{t-l}$	*0.231* *-1.761*		*0.331* *-1.405*		
Δ *ASCHM* $_{t-l}$		*-0.439* *(-2.791)*	*0.185* *-1.385*		
Δ *ASINY* $_{t-l}$ *i*				*-0.571* *(-1.973)*	
Δ *ASFINY* $_{t-l}$			*-0.168* *(-1.372)*		*-0.132* *(-2.028)*
Δ *ASIJKNY* $_{t-l}$			*0.086* *-1.419*		*-0.162* *(-1.544)*
Δ *CHCS* $_{t-l}$	*-0.181* *(-1.503)*		*-0.319* *(-1.502)*		
Δ *COCS* $_{t-l}$			*-0.148* *(-1.683)*	*-0.203* *(-1.360)*	

[a] t-statistic in parenthesis critical value at 10% significance level is 1.303.

Recall that Anderson and Bettencourt (1992) found survey results that show buyer preference on the west coast for Pacific over Atlantic salmon and conversely on the east coast. It is difficult to interpret the results in Table 5 and 6 as consistent with these survey observations. On the west coast, the price of chinook salmon (ΔCHCS) is measured to have no influence determining prices of Atlantic salmon (there is a lagged but statistically weak impact from the price of chinook salmon to the price of Atlantic salmon from Chile on the Los Angeles market (ASCHLA)). In other words, the price variations of Chinook salmon appear not to influence price formation of Atlantic salmon. On the other hand, on the West Coast the price of coho salmon appears to be more influential in determining the price of Atlantic salmon, having some influence in two of the four Atlantic equations. But the impact is not overwhelming. We do measure price linkage between the two Pacific species and, what is more, Atlantic prices are measured to have some determination on Pacific price formation (equations five and six, in Table 5). These results are more consistent with a story of Atlantic, not Pacific, prices being the primary determining force of salmon price determination on the west coast.

On the East Coast, the price linkage appears even more sparse. Here we observe little price interaction among the different Atlantic species. For example, the price of Atlantic salmon from Chile on the New York market has no measurable impact on any of the price equations. Similar findings are also had for the price of Atlantic salmon from Chile on the Miami market and Atlantic salmon from Faroe Island on the New York market. Clearly, these prices are independent of each other in the short run. However, one unambiguous conclusion is that the price of Faroe Island product, column three in table 7, is endogenous on the East Coast US market being influenced by all other salmon prices. Nevertheless, the short run results obtained for both East and West Coast regional markets show no or little substantial price linkage among the different salmon species.

Table 7 : Error Correction Models
Pacific and Atlantic Salmon

East Coast Markets (post 1991)

	Dependent Variable				
Independent Variables	Δ ASCHNY	Δ ASCHM	Δ ASFINY	Δ ASUKNY	Δ CHCS
Z_{t-l}	-0.651 (-4.726)a	-0.675 (-5.065)	*0.721* (-5.862)	-0.804 (-5.862)	-0.448 (-3.733)
Δ ASCHNY					
Δ ASCHM					
Δ ASINY	*0.29* *-3.064*		*0.325* *-2.003*		*0.124* *-1.339*
Δ ASFINY					
Δ ASUKNY			*0.163* *-2.473*		
Δ CHCS			*0.383* *-1.554*		
Δ COCS	*0.066* *-1.413*				
Δ ASCHNY $_{t-l}$	*0.231* *-1.761*	0.465 -2.146	*0.344* *-1.504*		
Δ ASCHM $_{t-l}$			*0.181* *-1.397*		
Δ ASINY $_{t-l}$ *i*				*-0.571* *(-1.952)*	
Δ ASFINY $_{t-l}$		*0.232* *-2.089*	*-0.162* *(-1.355)*		*-0.134* *(-2.041)*
Δ ASIJKNY $_{t-l}$			*0.089* *-1.504*	*-0.16* *(-1.512)*	
Δ CHCS $_{t-l}$	*-0.181* *(-1.489)*	*-0.459* *(-2.246)*	*-0.341* *(-1.650)*		
Δ COCS $_{t-l}$			*-0.145* *(-1.697)*	*-0.201* *(-1.324)*	

[a] t-statistic in parenthesis critical value at 10% significance level is 1.303.

Finally, it is of some interest to investigate whether these results change dramatically with the trade action by US against Norway. We re-estimate the equations for the East Coast market using data only after trade restrictions were imposed in 1991. The results for this estimation are shown in table 7. In comparing table 6 and 7, other than some minor changes in the estimated coefficients there appears to be little change in short run price interaction for the commodities investigated here. Certainly, Canada and Chile benefited from US trade action against Norway, but any short run price disruption on the US market is not measured in the data used here.

IV. Concluding Comments

In 1991, the US International Trade Commission stated that Atlantic and Pacific salmon species did not share a substitute relationship in any of the product forms. Such pronouncements deserve economic investigation. In this paper, we use regional US import prices of fanned Atlantic and Pacific salmon to investigate price linkage between the species. In modelling price linkage, Granger's short run error correction model allowing for long run market equilibrium is used in model specification. The results obtained are consistent with the existence of a general price equilibrium system, which includes both Atlantic and Pacific species. In a long run sense, the two species are substitute commodities. However, there appears to be a substantial amount of independence in short run price determination. In other words, short run arbitrage between the species, which would limit price deviation, is not measured in the data.

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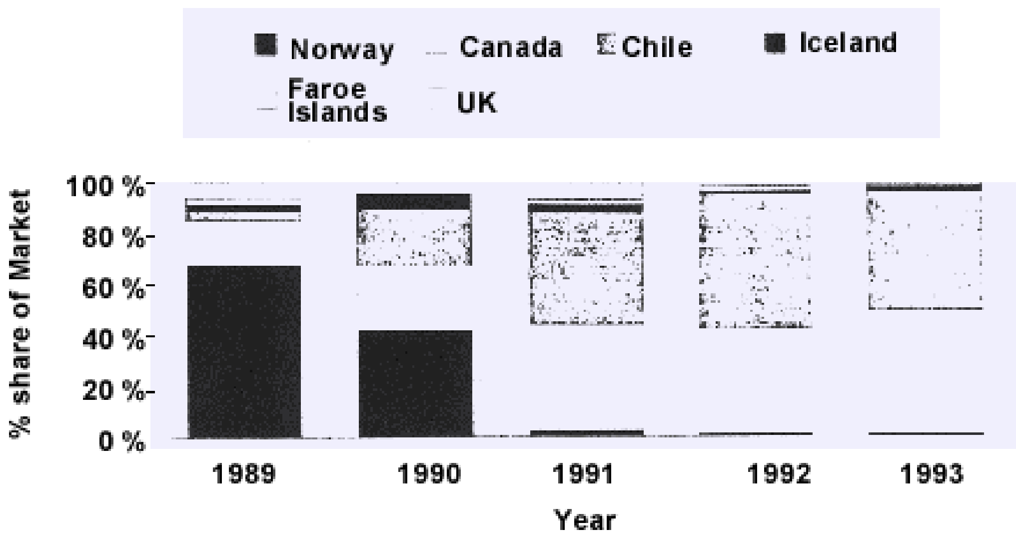
Table 1 United States Commercial Harvest of Pacific Salmon, 1987-92: tonnes

Species	1987	1988	1989	19911	1991	1992	Average
Chinook	18,116 (7%)	20,717 (8%)	14,273 (4%)	11.62 -4%	9,137 -3%	8,063 -3%	13,665 -4%
Coho	17,709 (7%)	21,540 (8%)	19,853 (5%)	21,540 -6%	25,107 (7%)	26.005 -8%	21,959 -7%
Sockeye	103,153 (41%)	86,200 (31%)	124,309 (35%)	143.934 -43%	121,925 (34%)	157,206 (48%)	122,788 (39%)
Chum	39,154 (15%)	66,437 (24%)	31,155 (9%)	31,842 (10%)	34,556 (10%)	41,010 (1,13%)	40,692 -13%
Pink	76,798 (30%)	80,054 (29%)	166,877 (47%)	123,557 (37%)	164,573 (46%)	92,416 -28%	117,379 -37%
Total	254,930	274,948	356,467	332,555	355,298	324,700	316,483

Source: Fisheries of the United States, NMFS (various issues), (annual share in parentheses)

Figure 1

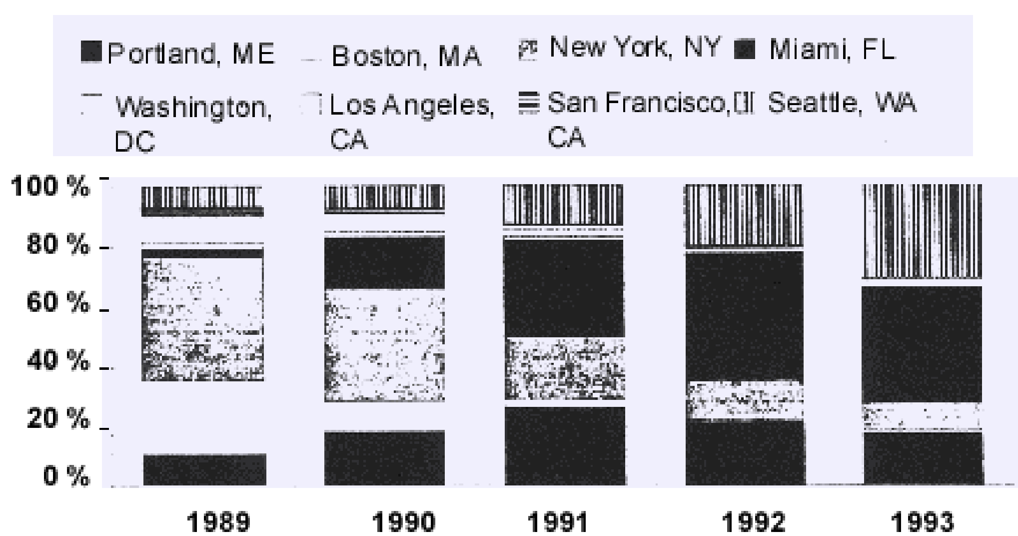
Market Shares of Major Supplying Countries
Fresh Atlantic Salmon, 1989-1993



SOURCE : U.S. Dept. of Commerce, NMFS, Import Statistics, 1989-1993.

Figure 2

Distribution of Imported, Fresh Atlantic Salmon
Among the Major U.S. Markets



SOURCE : U.S. Dept. of Commerce, NMFS, Import Statistics, 1989-1993.

Figure 3

Geographical Distribution of Fresh salmon Imports by Volume (1989)

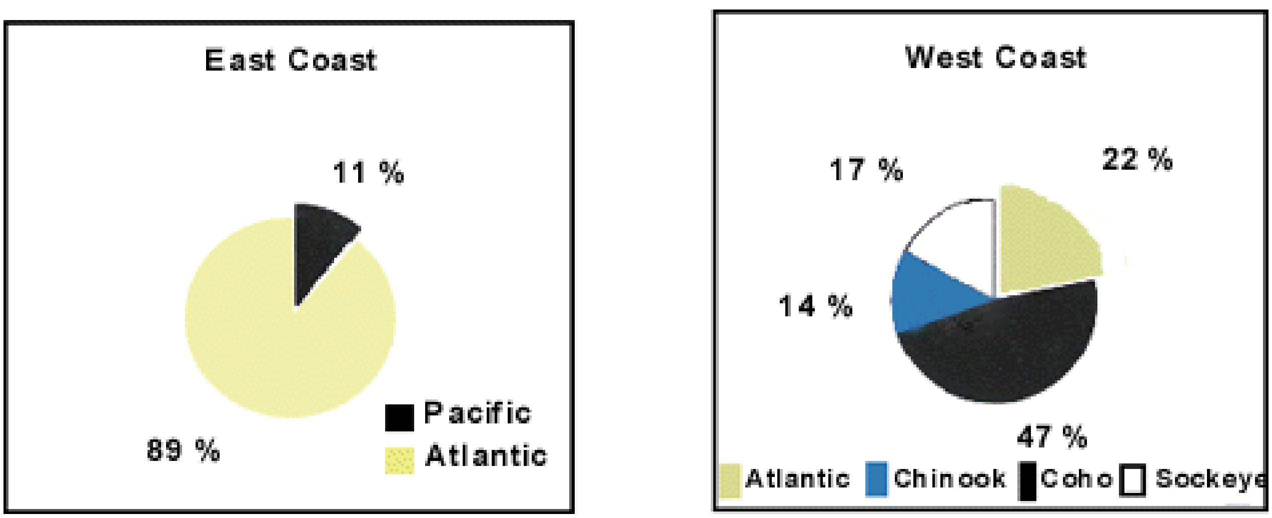


Figure 4

<u>Price Movements of Salmon 1989-1993</u>