QUANTITY AND EXCHANGE RATE EFFECTS ON U.S. TROUT PRICES

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QUANTITY AND EXCHANGE RATE EFFECTS ON U.S. TROUT PRICES

To describe the effects of quantity and the exchange rate on prices in the U.S. open fish market, this study develops an augmented differential inverse demand model. The model is applied to the U.S. trout market for empirical analysis. The augmented differential inverse CBS demand system (ADICBSDS) model provides overall theoretically consistent results.

INTRODUCTION

From 1991 to 2010 the nominal farm gate price of U.S. trout has increased at an annual rate of 2.03%. The real farm gate price, however, has decreased during that time period because of a higher inflation rate. This decrease in the real farm gate price combined with recent high feeding costs have most likely contributed to the decrease in U.S. trout production. In contrast, strong demand for value added seafood in the U.S. seafood market has increased U.S. trout imports from 1,754 to 7,410 tons during this same period. The market share of imported trout has increased from 6.2% in 1991 to 26.6% in 2010 - see Figure 1.

Nauman, Gempesaw, and Bacon (1995) indicated that U.S. trout producers have and will continue to experience keen competition from foreign producers and will need to develop more effective marketing techniques in order to maintain market share. The other side of this dramatic increase in U.S.
trout imports is a change in terms of the types of value added trout products, origins, and prices - see Table 1.²

<table>
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<th>Type</th>
<th>Origin</th>
<th>Import Volume (kg) 2010</th>
<th>Import Volume (kg) 1991</th>
<th>Δ%</th>
<th>Import Unit Value ($/kg) 2008</th>
<th>Import Unit Value ($/kg) 1991</th>
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<td>4,463</td>
<td>-</td>
<td>5.64</td>
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<td>1,753,642</td>
<td>322.57</td>
<td>7.57</td>
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</table>


Also, related to recent trends in U.S. currency valuation, the exchange rate has impact on the U.S. producer’s price and foreign exporter’s price in the U.S. trout market. In order to determine the impact the exchange rate has on the U.S. trout market, this study derived the augmented differential inverse demand system. The model is used for quantifying the effects of quantity and the exchange rate. According to the empirical analysis by using the model, the appreciation in currency value of the exporting country increases the U.S. trout price except for Canadian currency. Therefore, the recent devaluation of the U.S.
dollar against major exporting countries’ currencies supports the U.S. trout price. In contrast, the appreciation of exporter’s currency value decreases the exporter price.

This study proceeds in the following manner. In the next section we will discuss model development and focus on theoretical consistency while developing the model framework. In section three, we discuss empirical analysis where we describe features related to discrete data and statistical model. In section four we discuss the estimated results including quantity effects, exchange rate effects, and hypotheses tests. In the final section, the paper concludes by providing the major findings of this study and discussing their implications along with providing suggestions for future research.

MODEL DEVELOPMENT

Barten and Bettendorf (1989) explained price variations as functions of quantity variations. In doing so, they developed a set of inverse demand systems. Among inverse demand systems, the basic inverse demand system has the Rotterdam functional form which is expressed as:

\[ w_i d \ln \pi_i = h_i d \ln Q + \sum_{j=1}^{n} h_j d \ln q_j, \quad i, j = 1, ..., n, \]

where \( \pi_i = p_i / m \) is the normalized price of good \( i \); \( p_i \) and \( q_i \) are the nominal price and quantity of good \( i \), respectively; \( m = \sum_{i=1}^{n} p_i q_i \) is expenditure; \( w_i = p_i q_i / m \) is the expenditure share for good \( i \);

\[ d \ln Q = \sum_{i=1}^{n} w_i d \ln q_i \]

is the Divisia volume index.

Equation (1) defines the normalized price of good \( i \) as a function of the scale of consumption and the quantities consumed of the individual commodities.

In order to incorporate exchange rates into the inverse demand system, first let us examine the expenditure function. The expenditure function is the sum of expenditure shares as defined above. Totally differentiating the expenditure function yields:

\[ dm = \sum_{i} p_i dq_i + \sum_{i} q_i dp_i. \]
Dividing equation (2) by \( m \), multiplying and dividing the first term on the right hand side of equation (2) by \( q_i \), and multiplying and dividing the second term on the right hand side of equation (2) by \( p_i \), yields:

\[
\frac{dm}{m} = \sum_i p_i q_i \frac{dq_i}{m q_i} + \sum_i p_i q_i \frac{dp_i}{m p_i}.
\]

Since \( w_i = \frac{p_i q_i}{m} \) is the expenditure share of good \( i \), equation (3) can thus be rewritten as:

\[
d \ln m = \sum_i w_i d \ln q_i + \sum_i w_i d \ln p_i.
\]

Using the definition of both the Divisia price index \( (d \ln P = \sum w_i d \ln p_i) \) and the Divisia volume index, equation (4) becomes simply:

\[
d \ln m = d \ln P + d \ln Q.
\]

Now, let us assume that (i) there is a fish market for which \( n \) number of countries supply fish and (ii) each country uses a different currency. The conversion of an exporter's price into the importer's price is completed through the medium of the exchange rate and is expressed as follows:

\[
p_i = E_i p^*_i,
\]

where \( p_i \) is the importer’s price, \( p^*_i \) is the exporter’s price, and \( E_i \) is the exchange rate defined as the importer’s currency units per one unit of exporter’s currency so that \( E_i \) increases (decreases) when an exporter’s (importer’s) currency appreciates (depreciates).

Taking the logarithmic total differential of equation (6) yields:

\[
d \ln p_i = d \ln E_i + d \ln p^*_i.
\]

Then, the Divisia price index is decomposed into two parts as follows:

\[
d \ln P = \sum w_i (d \ln p_i) = \sum w_i (d \ln p^*_i + d \ln E_i) = d \ln P^* + \sum w_i d \ln E_i.
\]

Also, we can rewrite the dependent variable of equation (1) as follows:

\[
w_i d \ln \pi = w_i (d \ln p^*_i - d \ln P^*) - \sum_j w_i (w_j - \delta_{ij}) d \ln E_j - w_i d \ln Q
\]
where $\delta_{ij}$ is the Kronecker delta which is 1 when $i = j$ otherwise 0.

Then, equation (2) undergoes a series of modifications to obtain an augmented differential inverse CBS demand system (ADICBSDS) and is expressed as follows:

\begin{align*}
(10.1) & \quad w_i \left( d \ln p_i^x - d \ln P^x \right) = h_i d \ln Q + \sum_{j=1}^{n} h_{ij} d \ln q_j + \sum_{j=1}^{n} w_i (w_j - \delta_{ij}) d \ln E_j + w_i d \ln Q, \\
(10.2) & \quad w_i \left( d \ln \frac{p_i}{P^x} \right) = (h_i + w_i) d \ln Q + \sum_{j=1}^{n} h_{ij} d \ln q_j + \sum_{j=1}^{n} w_i (w_j - \delta_{ij}) d \ln E_j, \\
(10.3) & \quad w_i \left( d \ln \frac{p_i}{P^x} \right) = c_i d \ln Q + \sum_{j=1}^{n} h_{ij} d \ln q_j + \sum_{j=1}^{n} c_j d \ln E_j,
\end{align*}

where $c_i$ is the scale flexibility coefficient, $h_{ij}$ is the price flexibility coefficient, and $c_j$ is the exchange-rate coefficient. The dependent variable now involves the relative price for good $i$ rather than the normalized price. The relative price represents exporter price rather than importer price. The right hand side includes not only scale and quantity variables but also the exchange-rate variable. As a result, the derived equation can be used to identify the variation of exporter price not only as quantity supplied but also from changes in the exchangerate.

Microeconomic theory implies the following parametric restrictions:

\begin{align*}
(11.1) & \quad \sum c_i = 0 \quad \text{and} \quad \sum h_{ij} = 0 \quad \text{adding-up} \\
(11.2) & \quad \sum h_{ij} = 0 \quad \text{homogeneity} \\
(11.3) & \quad h_{ij} = h_{ji} \quad \text{Antonelli symmetry.}
\end{align*}

Scale and price flexibilities corresponding to equation (10.3) are computed from the following formulas:

\begin{align*}
(12.1) & \quad f_i = \frac{c_i}{w_i} - 1 \quad \text{scale flexibility} \\
(12.2) & \quad f_{ij} = \frac{h_{ij}}{w_i} \quad \text{compensated price flexibility}
\end{align*}
In addition, the exchange-rate coefficients, $c_{ij}$, obey the classical restrictions on consumer demand, namely:

(13.1) $\sum c_{ij} = 0$ adding up

(13.2) $\sum_j c_{ij} = 0$ homogeneity

(13.3) $c_{ij} = c_{ji}$ for all $i \neq j$ Antonelli symmetry

Exchange rate flexibilities are computed using the formulas:

(14) $z_{ij} = \frac{c_{ij}}{w_i}$.

The exchange-rate flexibility given in equation (14) indicates the response of relative price to changes in the exchange rates. The corresponding expressions for the response of absolute price to changes in exchange rate are derived as follows:

(15.1) $(d \ln p'_i - d \ln P^s) = \frac{h_i}{w_i} d \ln Q + \sum_{j=1}^n h_{ij} d \ln q_j + \sum_{j=1}^n \frac{c_{ij}}{w_i} d \ln E_j$,

(15.2) $\frac{\partial \ln p'_i}{\partial \ln E_j} - \frac{\partial \ln P^s}{\partial \ln p'_i} \frac{\partial \ln p'_i}{\partial \ln E_j} = c_{ij} \frac{1}{w_i}$,

(15.3) $\frac{\partial \ln p'_i}{\partial \ln E_j} (1 - w_i) = c_{ij} \frac{1}{w_i}$, and simply expressed as

(15.4) $z_{ij}' = \frac{c_{ij}}{w_i (1 - w_i)}$.

Putting $c_{ij} = w_i (w_j - \delta_{ij})$ into equation (15.4), the absolute price flexibilities in terms of expenditure shares are:

(16.1) $z_{ij}' = -\frac{w_i (1 - w_j)}{w_i (1 - w_j) = -1 \quad \text{own effect}$
Thus, to test whether the fish market is efficient in the sense that exchange rate pass-through is complete, it is sufficient to test whether estimated own-exchange rate flexibilities, as defined by equation (15.4), are equal to minus one.

**EMPIRICAL ANALYSIS**

**Empirical Specification**

This study applies the model developed above to the U.S. trout market. The main reason for developing our pricing model is to obtain reliable quantity and exchange-rate flexibilities because they provide information about inter-product relationships in the open market. A five-equation system is formulated to represent the five major suppliers of trout to the U.S. market, namely the United States \((i=1)\), Argentina \((i=2)\), Canada \((i=3)\), Chile \((i=4)\), and the rest of the world (ROW) \((i=5)\). Thus, we implicitly assume that trout is weakly separable from all other goods, including other fish species.

Differentials are approximated using finite time differences. Thus, \(d \ln x_i\) is approximated as \(\Delta \ln x_i = \ln x_{i,t} - \ln x_{i,t-1}\), where subscript \(t\) indexes time. Intercepts are generally included in differential demand systems to account for gradual changes in tastes (Deaton and Muellbauer 1980, pp.69-70). Thus, the final estimating equation takes the form:

\[
(17) \quad \overline{w}_{i,t} \left( \Delta \ln \frac{P_{i,t}^x}{P_t^x} \right) = \alpha_i + c_i \Delta \ln Q_t + \sum_{j=1}^{5} h_{ij} \Delta \ln q_{j,t} + \sum_{j=2}^{5} c_{ij} \Delta \ln E_{j,t} + \varepsilon_{i,t},
\]

where \(\overline{w}_{i,t} = (w_{i,t} + w_{i,t-1})/2\), \(\Delta \ln Q_t = \sum_{j=1}^{5} \overline{w}_{j,t} \Delta \ln q_{j,t}\), \(\Delta \ln P_t^x = \sum_{j=1}^{5} \overline{w}_{j,t} \Delta \ln p_{j,t}^x\), and \(\varepsilon_{i,t}\) is a random disturbance term.\(^3\) Adding-up is enforced by imposing the added restriction \(\sum \alpha_i = 0\).
The model includes five source specific trout and four macro-economic variables, i.e., exchange rates of U.S. Dollar – Canadian Dollar, U.S. Dollar – Argentina Peso, U.S. Dollar – Chilean Peso, U.S. Dollar – currency of ROW (we used the Uruguayan Peso as the ROW unit of currency). This study obtained annual price and quantity data of these source specific products from 1991 to 2010 from various sources. Price and quantity data for U.S. food-size trout were obtained from the U.S. National Agricultural Statistics Service (NASS), quantity and value data for imported trout were obtained from the U.S. National Marine Fisheries Service (NMFS), and exchange rate data were obtained from the International Monetary Fund (IMF). The unit prices of imported trout were obtained by dividing total value by the volume of imports. The quantity and price data obtained represent an actual quantity (kilograms) and an actual price (dollars per kilogram). These data were normalized and differentiated following the model framework. Differencing results in the loss of one observation. Hence, the model is estimated with 19 observations (1991 through 2010). The fifth equation (i=5) is deleted during estimation to avoid singularity in the residual covariance matrix of the full model. The coefficients of the deleted equation were recovered using the adding-up conditions. The model was estimated using the Seemingly Unrelated Regressions (SUR) estimator in SAS. Homogeneity and symmetry for quantity are restricted in the estimating procedure, while exchange-rate homogeneity and symmetry were tested prior to imposition.

**Statistical Validity**

This study tested multivariate and univariate tests of normality of the ADICBSDS model. The multivariate tests are Mardia’s skewness and Kurtosis test and the Henze-Zirkler $T_{i,p}$ test. The univariate test employed is the Shapiro-Wilk $W$ test. The null hypothesis for all these tests is that the residuals are normally distributed. Test results from the multivariate and univariate tests show that the ADICBSDS model did not reject the null hypothesis at the 5% significance level.

A question related to variable selection is that of choosing the most appropriate functional form for a particular economic relationship. Ideal tests of functional form have high power over a wide variety of alternative hypotheses. A RESET type test, which uses powers (2nd and higher orders) of the model’s
fitted values ($\hat{y}$) can be viewed as a general functional form test (Ramsey 1969). The RESET tests use $F$-statistics to assess the significance of the predictions in an auxiliary regression in which the squares and the higher powers of the model’s fitted values are used as additional explanatory variables. Significance of the coefficients of the additional variables is intended to be indicative of some kind of specification error related to the underlying augmented LDIAIDS model (i.e., incorrect functional form). Except for $F$-statistics in RESET2 and RESET3 of imported frozen and rainbow trout price equations, $F$-statistics were lower than the critical value at the 5% significance level.

One of the key assumptions of an econometric regression is that the variance of the disturbances is constant across observations. If the residuals of the ADICBSDS model have constant variance, as assumed herein, the ADICBSDS model will provide an efficient, unbiased estimator with a consistent variance. This study used the Godfrey Lagrange Multiplier (LM) test for checking for the presence of static homoskedasticity. The null hypothesis in this particular test is that the covariance matrix of residuals is homoskedastic. The test results showed no static heteroskedasticity at the 5% level.

Because it is not possible for this study to use monthly data, annual data was used. The main motivation for estimating an inverse demand system is that quantities are assumed to be naturally predetermined. Fish supply, however, can respond to price incentives and the actual quantity supplied annually is likely to be influenced by random fluctuations in that year’s price. As a result, the assumption of predetermined quantity might be questioned. Taking this into account, this study tested the predeterminedness of annual quantities with the Wu-Hausman test (see Park, Thurman, and Easley, 2004 and Thurman, 1986). The $\chi^2$ statistic of the test was 5.20 with 30 degrees of freedom, less than the 10 percent critical value in the chi-square distribution of 40.3. Essentially, the test for the pre-determinedness of quantities could not reject the null hypothesis so the restricted SUR estimates are further substantiated by this evidence.
Hypothesis Tests

The relative importance of import growth and exchange rate movements in price formation is tested via the following hypothesis:

(18) \( H_0 : c_{ii} = h_{ii}, \quad i = 1,...,5, \)

The null hypothesis confirms that own exchange rate effects are equal to (compensated) own quantity effects; i.e., \( z_{ii} = f_{ii}^A. \)

Also, in order to test whether exchange rate pass-through is complete we tested:

(19) \( H_0 : c_{ii} = -w_i(1-w_i), \quad i = 1,...,5, \)

The null hypothesis confirms that absolute priceown exchange rate effects equal minus one; i.e., \( z_{ii}^A = -1. \) Hypotheses (18) and (19) were tested using the \( F \)-statistic. The results of the two hypotheses tests will be discussed in the following Results and Discussion section.

RESULTS AND DISCUSSION

Before discussing the estimated flexibility coefficients, let us discuss the test results of exchange rate homogeneity and symmetry. Exchange rate homogeneity and symmetry are not rejected at \( \alpha = 5\% \) (see table 2). However, imposition of the restrictions might have effects upon parameters estimated by the statistical model. Therefore, the model was estimated with and without the restrictions as to confirm whether those parameters are unduly affected (or not). Results show that the parameters were only slightly affected by the imposition of the aforementioned restriction. Also, model fitness \((R^2)\) is only slightly affected as well. Therefore, the following discussion holds relatively the same, whether the restrictions have been imposed or not.

Overall estimations are satisfactory in terms of that the estimated scale flexibilities are negative (implying normal goods), uncompensated own price flexibilities are negative (implying downward sloping of the demand curve), own exchange rate flexibilities are negative (implying an inverse relationship between the exporter’s currency value and price). The U.S. equation has the best explanatory
power ($R^2=0.88$), followed by ROW (0.85), Argentina (0.81), Chile (0.80), and Canada (0.65). The intercept of ROW is significant and positive, implying that taste and preferences for trout from ROW may be strengthening over time. In contrast, the intercept of Canada is significant and negative, implying that taste and preferences for trout from Canada may be weakening over time. The intercept of the other countries are not significant. The estimated coefficients for the Divisia volume index are not significant for Argentina, Canada, and ROW, implying that preferences for trout from these countries are homothetic (expenditure elasticity equal to one). The estimated coefficient of the Divisia volume index is positive and significant for Chilean trout, implying that Chilean trout is a superior good (expenditure elasticity greater than one). The estimated coefficient of the Divisia volume index is negative and significant for U.S. trout, implying that U.S. trout is a normal good (expenditure elasticity is between zero and one).

The relative importance of quantity and the exchange rate in price formation vary depending on source specific trout. For example, the own quantity effect of Canadian trout is estimated with a high degree of precision ($t$ ratio $> \text{critical value at } \alpha = 0.01$) while the own exchange-rate effect of Canadian trout is insignificant. This result indicates the potential importance of quantity in price formation for Canadian trout. In contrast, the own quantity effect of Chilean trout is insignificant while the own exchange-rate effect is estimated with a high degree of precision ($t$ ratio $> \text{critical value at } \alpha = 0.01$). This result indicates the potential importance of the exchange rate in price formation for Chilean trout. The own quantity and exchange rate effects of Argentine trout are estimated with high degrees of precision ($t$ ratios $> \text{critical value at } \alpha = 0.05$). This result indicates the equal importance of quantity and exchange rate in price formation for trout sourced from Argentina.
Quantity Effects

The scale and price flexibilities are reported in table 3. The estimated scale flexibilities are -1.13 for the United States, -1.06 for Argentina, -1.07 for Canada, -0.49 for Chile, and -1.14 for ROW, respectively. These estimates suggest a 1% increase in the scale of supply in the U.S. trout market would cause relative prices in suppliers’ currencies to decline by 1.13% for the United States, 1.06% for Argentina, 1.07% for Canada, 0.49% for Chile, and 1.14% for ROW, respectively, given constant exchange rates.

Compensated flexibilities show a similar pattern as has been noted in previous studies. For example, most of the off-diagonal elements of the compensated flexibilities matrix are positive, implying net cross complementarity. This result is counterintuitive because imported trout are usually recognized as substitutes for U.S. trout. As explained by Barten and Bettendorf (1989), the reason for this counterintuitive result is that the homogeneity restriction on the compensated responses ($\sum_i h_{ij} = 0$) combined with the negative semi-definiteness of the Antonelli matrix prejudices results toward complementarity. However, this study found that most of diagonal elements of the matrix are positive except for ROW. This result violates the assumption of negative semi-definiteness of the Antonelli matrix and implies own net complementarity. Therefore, the dominance of net complementarity in off-diagonal elements might come from the structure of preferences but not from the conditions of homogeneity and negative semi-definiteness. To make this problem clearer, interaction effects have been discussed in terms of the uncompensated flexibilities or Allais coefficients, Barten and Bettendorf (1989). As shown in

<table>
<thead>
<tr>
<th>Null Hypothesis</th>
<th>Number of Restrictions</th>
<th>F-value</th>
<th>H₀ at α = 0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homogeneity</td>
<td>4</td>
<td>2.22</td>
<td>Do not reject</td>
</tr>
<tr>
<td>Symmetry</td>
<td>3</td>
<td>1.44</td>
<td>Do not reject</td>
</tr>
<tr>
<td>Homogeneity &amp; Symmetry</td>
<td>7</td>
<td>3.11</td>
<td>Reject</td>
</tr>
</tbody>
</table>

Critical F-values at α = 0.05: $F_{4/40} = 2.61$, $F_{3/40} = 2.84$, and $F_{7/40} = 2.25$. 

<table>
<thead>
<tr>
<th>Null Hypothesis</th>
<th>Number of Restrictions</th>
<th>F-value</th>
<th>H₀ at α = 0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homogeneity</td>
<td>4</td>
<td>2.22</td>
<td>Do not reject</td>
</tr>
<tr>
<td>Symmetry</td>
<td>3</td>
<td>0.59</td>
<td>Do not reject</td>
</tr>
<tr>
<td>Homogeneity &amp; Symmetry</td>
<td>7</td>
<td>1.67</td>
<td>Do not reject</td>
</tr>
</tbody>
</table>
Table 3, the uncompensated flexibilities are uniformly negative, indicating all five products are gross substitutes.

The estimated uncompensated own flexibilities are -0.65 for the United States, -0.01 for Argentina, -0.02 for Canada, -0.09 for Chile, and -0.10 for ROW, respectively. As Houck (1966) indicated, these estimates suggest that the demands for five source-specific trout groupings are price elastic because the inverse of the absolute value of the own-price flexibility sets the lower bound on the own-price elasticity. One of the results in this study that does differ from previous study results relates to uncompensated cross flexibilities. The uncompensated cross flexibilities in the five equations are greater in absolute value than their own uncompensated flexibilities. This implies that increases in quantity supplied from foreign countries have larger depressing effects on price (in magnitude) than do similar increases in trout supply sourced from trout exporting countries into the U.S. trout market. For example, the U.S. trout price decreases by 0.65% when the U.S. trout supplied increases by 1% while U.S. trout price decreases by 0.67%, 0.68%, and 0.66% for a 1% increase in trout imports from Argentina, Canada, and Chile, respectively. Thus, an increase in imports from Argentina, Canada, and Chile has a large depressing effect on U.S. trout price than does a similar increase in supply from U.S. producers. This is not expected result because the U.S. trout dominates the market.

<table>
<thead>
<tr>
<th>Equation</th>
<th>$f_i$</th>
<th>$f_{i1}$</th>
<th>$f_{i2}$</th>
<th>$f_{i3}$</th>
<th>$f_{i4}$</th>
<th>$f_{i5}$</th>
<th>$f_{i1}$</th>
<th>$f_{i2}$</th>
<th>$f_{i3}$</th>
<th>$f_{i4}$</th>
<th>$f_{i5}$</th>
<th>$w_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-1.128</td>
<td>0.011</td>
<td>-0.009</td>
<td>-0.018</td>
<td>0.006</td>
<td>0.010</td>
<td>-0.654</td>
<td>-0.674</td>
<td>-0.684</td>
<td>-0.659</td>
<td>-0.655</td>
<td>0.59</td>
</tr>
<tr>
<td>2</td>
<td>-1.058</td>
<td>-0.094</td>
<td>0.049</td>
<td>0.025</td>
<td>-0.006</td>
<td>0.027</td>
<td>-0.153</td>
<td>-0.010</td>
<td>-0.034</td>
<td>-0.065</td>
<td>-0.032</td>
<td>0.06</td>
</tr>
<tr>
<td>3</td>
<td>-1.073</td>
<td>-0.124</td>
<td>0.016</td>
<td>0.077</td>
<td>0.010</td>
<td>0.022</td>
<td>-0.217</td>
<td>-0.077</td>
<td>-0.016</td>
<td>-0.083</td>
<td>-0.071</td>
<td>0.09</td>
</tr>
<tr>
<td>4</td>
<td>-0.489</td>
<td>0.017</td>
<td>-0.002</td>
<td>0.004</td>
<td>0.015</td>
<td>-0.034</td>
<td>-0.083</td>
<td>-0.102</td>
<td>-0.096</td>
<td>-0.086</td>
<td>-0.134</td>
<td>0.20</td>
</tr>
<tr>
<td>5</td>
<td>-1.143</td>
<td>0.072</td>
<td>0.014</td>
<td>0.020</td>
<td>-0.084</td>
<td>-0.010</td>
<td>-0.019</td>
<td>-0.077</td>
<td>-0.071</td>
<td>-0.175</td>
<td>-0.102</td>
<td>0.08</td>
</tr>
</tbody>
</table>

**Exchange Rate Effects**

Exchange rate flexibilities for both relative and absolute price are reported in Table 4. Most of the estimated coefficients have the correct sign, and twelve among twenty estimated coefficients are
significant at least at the 5% significance level. The relative and absolute price flexibilities differ in expected ways. In particular, the absolute price exchange rate flexibilities are larger in absolute value than their relative price counterparts, but otherwise are identical in sign. Thus, we will restrict, for brevity, our attention to the absolute price flexibilities as they are somewhat easier to interpret. In particular, $z_i^A = -1$ signifies that exchange rate pass-through is complete.

Of the four exchange rate indices studied, the ROW index has the largest influence on its’ own export price. The basis for this statement is that the estimated own exchange rate flexibilities coefficients of $E_5$ in equation 5 is significant at the 1% level and the estimated flexibilities for $E_5$ is greater (in absolute value) than those of $E_2$ in equation 2, $E_3$ in equation 3, and $E_4$ in equation 4. According to these estimates, an isolated 1% strengthening in the currency value of ROW reduces ROW export price by 1.59% while an isolated 1% strengthening in the currency value of Argentina, Canada, and Chile reduces their own export prices by 0.35%, 0.02%, and 0.18%, respectively. For the U.S. price, only a theoretically consistent result is obtained in Canadian currency. An isolated 1% strengthening in the Canadian Dollar against the U.S. Dollar decreases the U.S. price by 0.09%.

### Hypothesis Tests

Test results for hypotheses (18) and (19) are reported in table 5. Tests were performed with the homogeneity and symmetry restrictions imposed. Focusing first on hypothesis (18), results are mixed in which some of the currencies are as important as quantity while not as much in others. For example, currency realignments of Canada and Chile are at least as important as supply growth in the price

<table>
<thead>
<tr>
<th>Equation</th>
<th>$z_{i2}$</th>
<th>$z_{i3}$</th>
<th>$z_{i4}$</th>
<th>$z_{i5}$</th>
<th>$z_{i2}^{A}$</th>
<th>$z_{i3}^{A}$</th>
<th>$z_{i4}^{A}$</th>
<th>$z_{i5}^{A}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.011</td>
<td>-0.150</td>
<td>0.061</td>
<td>0.078</td>
<td>0.027</td>
<td>-0.367</td>
<td>0.149</td>
<td>0.190</td>
</tr>
<tr>
<td>2</td>
<td>-0.329</td>
<td>0.001</td>
<td>0.210</td>
<td>0.118</td>
<td>-0.348</td>
<td>0.001</td>
<td>0.222</td>
<td>0.124</td>
</tr>
<tr>
<td>3</td>
<td>0.001</td>
<td>-0.015</td>
<td>0.113</td>
<td>-0.129</td>
<td>0.001</td>
<td>-0.017</td>
<td>0.124</td>
<td>-0.141</td>
</tr>
<tr>
<td>4</td>
<td>0.049</td>
<td>0.041</td>
<td>-0.139</td>
<td>0.049</td>
<td>0.064</td>
<td>0.054</td>
<td>-0.182</td>
<td>0.064</td>
</tr>
<tr>
<td>5</td>
<td>0.294</td>
<td>-0.056</td>
<td>0.501</td>
<td>-1.546</td>
<td>0.301</td>
<td>-0.058</td>
<td>0.514</td>
<td>-1.585</td>
</tr>
</tbody>
</table>
formation of trout in the U.S. market because the hypothesis \( f_{ii} = z_{ii} \) fails to be rejected in Canada and Chile. However, the hypothesis for Argentina and ROW are rejected. For Argentina, the exchange rate seems to play a more central role in price formation than does quantity supplied because the estimated own exchange rate flexibility are greater in absolute value than the estimated own uncompensated flexibilities. For ROW, in contrast, quantity supplied seems to play a more important role in price formation than does the exchange rate because the estimated own uncompensated flexibilities are greater in absolute value than the estimated own exchange rate flexibilities.

Turning to hypothesis (19), results show that all currencies show incomplete pass-through. For example, the hypothesis \( z_{ii}^d = -1 \) is rejected for all currencies. Thus, it would appear that the U.S. trout market is inefficient with respect to trout trade. In particular, the exchange rate pass-through of Canadian currency is very low compared to the other currencies.

<table>
<thead>
<tr>
<th>Equation</th>
<th>Equivalency of Exchange Rate and Quantity Effects&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Complete Exchange Rate Pass-Through&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( F )-value ( p )-value ( H_0 )</td>
<td>( F )-value ( p )-value ( H_0 )</td>
</tr>
<tr>
<td>2</td>
<td>11.51 0.001 Reject</td>
<td>30408 0.000 Reject</td>
</tr>
<tr>
<td>3</td>
<td>0.06 0.811 Do not reject</td>
<td>2095 0.000 Reject</td>
</tr>
<tr>
<td>4</td>
<td>0.74 0.394 Do not reject</td>
<td>547 0.000 Reject</td>
</tr>
<tr>
<td>5</td>
<td>10.99 0.002 Reject</td>
<td>6816 0.000 Reject</td>
</tr>
</tbody>
</table>

<sup>a</sup>\( H_0: f_{ii} = z_{ii} \)

<sup>b</sup>\( H_0: z_{ii}^d = -1 \)

**CONCLUSIONS**

One common denominator in the U.S. seafood market is an increasing trend of import competition. Since each exporting country uses a different currency, a degree of efficiency in converting the exporting country’s currency into U.S. Dollars is as important as the role which quantity supplied plays in determining price formation in the U.S. trout market. These two foci were the primary sources of motivation for this study. Many previous studies have provided a theoretically solid foundation for the price formation of fish. Most of them are related to a systems approach rather than that of a single equation model because systems approach could examine the theoretical consistency of the model.
Among the systems approaches, inverse demand systems have been popular. Although traditional inverse demand systems are useful in identifying the role of quantity supplied in determining price formation, the authors deemed that a new theoretical framework that incorporated the exchange rate into the traditional inverse demand system was warranted. In this context, the recent study conducted by Xie, Kinnucan, and Myrland (2008) provides a critical piece of information that augmented the development of a theoretical framework to achieve our objectives.

We used the U.S. trout market for an empirical application of the augmented inverse demand system because trout imports have increased dramatically during the sample period and according to a change in consumer preference for high quality there has been a distinct change in exporting countries’ shares of trout to the U.S. trout market. Overall empirical results are consistent with economic theory and results found in previous studies. Of our results, first, the estimated uncompensated own flexibilities showed a downward sloping demand curve. Second, own exchange rate flexibilities are estimated in a manner that is consistent with a principal tenet of trade theory that indicates that, with a currency appreciation for an exporting country, exporter prices are expected to decrease. Third, gross effects of own and cross quantities are negative while net effects of own and cross quantities are a mixture of both positive and negative results. Fourth, the gross effects of own quantities are greater than the net effects of own quantities when the net effect of own quantity is negative.

Although the empirical results are similar with previous studies two distinct results are found. First, complementarities in most of the cross compensated flexibilities are not related to substitutability of own compensated flexibilities because the own compensated flexibilities are positive in this study. This result implies that the dominance of complementarity in the off-diagonal elements might come from the structure of preferences rather than from the conditions of homogeneity and negative semi-definiteness. Second, cross uncompensated flexibilities are greater in absolute value than the own uncompensated flexibilities in this study. This result implies that U.S. trout prices are depressed (in magnitude) more by
imported products than by any increases in the availability of U.S. trout products. As a result, the trend of increasing trout imports may be a response to recent downsizing in the U.S. trout industry.
Footnote 1. According to the U.S. Department of Labor, the average annual rate of inflation was 3.2% for the sample time period.

Footnote 2. According to the U.S. International Trade Commission, representative products of imported trout are: 1) frozen fillets (HS: 0304206005), 2) fresh or chilled whole trout (HS: 0302110090), 3) frozen whole trout (HS: 0303210000), and 4) farmed fresh rainbow trout (HS: 0302110010). Rates of duty are applied to each HS code. However, since the duty amount of each product is relatively small compared to the imported price, this study ignores the duty amount in discussing the imported price. Rates of duty are 5.5¢/kg for HS 0304206005 and 2.2¢/kg for HS 0302110090, 0303210000, and 0302110010.

Footnote 3. This index results in a simultaneity problem since the expenditure share in the index, \( w_{t+1} \), is also the dependent variable. To avoid this in the empirical model, the lagged share (Eales and Unnevehr, 1988) or average share (Haden, 1990) has been used.
REFERENCES


