Analysis of United States and European Union Import Demand for Shrimp

Pawan Poudel and Walter Keithly Jr.
Graduate Student and Assoc. Professor
Department of Agriculture Economics
Louisiana State University

Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Dallas, TX, February 2-6, 2008

Abstract

Based on 1990-2004 quarterly data, U.S. and E.U. demand for imported shrimp by alternative supply sources was examined within an Almost Ideal Demand System framework. For the United States, supply sources included Central America, South America, and Asia. Supply sources for the European Union included Asia, South America, and Rest of World. All own-price elasticities for the U.S. system were found to be elastic while all own-price elasticities associated with the E.U. system were found to be inelastic. With few notable exceptions, estimated cross-price elasticities suggest substitution among import sources. Finally, shrimp of Asian origin were found to be highly expenditure elastic in the US market while shrimp of South American origin were found to be the same in the European market.

1. Introduction:

The world shrimp market has expanded significantly since the 1980s. World exports of shrimp, valued at $10.9 billion, constituted approximately 17% of the 2003 $63 billion international seafood market (FAO). The increase in shrimp trade has been attributed primarily to increased production; the result of an expansion in aquaculture operations (primarily in Asia and South America). Overall, world shrimp production (cultured and wild) advanced from 3.4 billion pounds (live weight) in 1980 to 10.3 billion pounds in 2003.

With annual growth in supply exceeding that of demand, export prices have been trending downwards since the early-to-mid 1980s. In 1980, for example, the deflated export price equaled $3.22 per product-weight pound (FAO).[1] By 2003, the price had fallen to $ 1.47 per pound. During the same period, the traded volume increased from around 900 million pounds to around 4 billion pounds.

The United States and Japan have historically been the two primary destination markets for the exported shrimp product (particularly, warm-water shrimp). In 2004, the United States imported 1.13 billion pounds of shrimp (product weight), valued at $3.89 billion. Japanese imports for the same year totaled 504 million pounds, valued at $1.94 billion. Overall, U.S. imports of shrimp have more than doubled since 1990 when they equaled 501 million pounds (product weight). By comparison, little growth in the Japanese import market has been evident since 1990 when imports totaled 637 million pounds.

[1] The U.S. Consumer Price Index (1982-84 = 100) was used as a deflator.

The European shrimp market has experienced considerable growth in recent years. While the European Union has traditionally preferred cold water shrimp, the majority of the recent growth has been of the warm water variety. Many of the countries that have increased exports to the EU in recent years also export to either the U.S. or Japan (or both countries). Together, these three (group of) countries, the US, EU and Japan account for a minimum of 60% of the world trade in shrimp.

While shrimp is one of the primary seafood commodities traded in the world seafood market, little work has been conducted to assess the degree to which import demand changes as relative prices of the exported product, by region, varies. Using the Almost Ideal Demand System approach, this paper investigates the U.S. and European Union demand for imported shrimp from various producing regions.

2. Data and Methods

This study uses the Linear Approximation of Almost Ideal Demand System (AIDS) to model the demand for imported shrimp by the United States and the European Union. All equations in the demand system are modeled using quarterly data covering the 1990 through 2004 period.

For the U.S. demand system, three regions – Asia, South America, and Central America – are considered. These three regions account for more than 95% of the U.S. import market.[2] While the European Union imports a significant amount of shrimp from Asia and South America, it imports virtually no product from Central America. However, it imports a large amount of cold-water shrimp. Hence, the three regions considered in the E.U. demand system are Asia, South America, and the Rest of World.[3] Some summary statistics associated with U.S. and E.U. imports are presented in Table 1.

Table 1: Summary statistics.

U.S. Imports						
Region	**Quantity (Million lbs)**			**Price (Deflated US $)**		
	Mean	**Min.**	**Max.**	**Mean**	**Min.**	**Max.**
Asia	109.800	52.349	282.221	2.603	1.592	3.389
South America	39.289	21.654	61.496	2.171	1.181	2.917
Central America	29.195	9.696	65.763	2.704	1.761	3.370
E.U. Imports						
Asia	49.031	28.853	103.654	2.112	1.324	2.760
South America	24.994	9.124	70.451	2.038	1.065	2.878
Rest of the World	86.330	39.363	166.867	1.408	0.992	2.219

Typical studies using the AIDS framework assume that prices are unresponsive to changes in demand and use an Iterative Seemingly Unrelated Regression (ITSUR) method to estimate the parameters. Given the structure of the world shrimp market, however, it seems unlikely that changes in demand in a given country (region) would not influence price.[4] Asia is the largest shrimp exporter to all the three major importers (i.e., US, EU and Japan) and one can assume that a change in demand in any of these countries

[2] The remaining product exported to the United States is primarily cold-water shrimp from Europe. In addition to these three regions, the United States also produces from about 180 million pounds (headless shell-on weight) to 215 million pounds annually. Most of this production represents warm-water shrimp produced in the Gulf and South Atlantic. There is relatively little variation in annual production which accounted for approximately 20% of the total U.S. supply (i.e., imports and domestic production) during the period of analysis. Given limited variation in annual quantity of domestic product, this product was not included in the analysis. This implies that demand for imported product (by region) is independent of the price/quantity of domestic product.

[3] "Rest of World" is used to denote all E.U. imports with the exception of those imports from Asia and South America (warm-water shrimp). Most of these imports reflect cold-water shrimp species. The category, however, also includes some South American countries producing cold-water shrimp (e.g., Argentina).

[4] In general, an unresponsive price to a change in a country's demand would suggest a residual market for the product in that country.

(regions) will result in a change in the export prices to the different countries (regions). Similarly, South American shrimp has significant market share in both the US and the EU, and we can safely assume that changes in demand in either region will influence the export price to that region. Whal and Hayes (1990) suggest that imposing the assumption of perfectly elastic supply may lead to simultaneous equations bias, causing underestimation of price responsiveness. They compare the results of ITSUR estimations (assuming supply to be perfectly elastic) with iterative three stage least squares (IT3SLS) estimations (assuming supply to be upward sloping), and show that ITSUR results underestimate the elasticities.

Given this situation, the import demand equations are estimated using IT3SLS procedure. These results are compared to the results obtained from iterative seemingly unrelated regression.

For purposes of analysis, cultured and wild production from the various exporting regions, incomes, exchange rates, dummy variables for the first three quarters of each year, and the trend variable are defined as exogenous to the model for IT3SLS estimation. Import prices and import quantities are considered to be endogenous variables.

Data used in the analysis are readily available online. Production data is available only on annual basis, while quarterly data are required for analysis. Assuming only limited storage capacity in producing regions, annual production for Asia and South America (both cultured and wild) were converted to a quarterly basis based on quarterly import shares by the primary importing regions (i.e., Japan, the United States, and the European Union). Central American production was converted to a quarterly estimates based on numbers that can be found in Keithly and Diagne (1998)[5].

3. Almost Ideal Demand System

Since its introduction by Deaton and Muellbauer in 1980, the Almost Ideal Demand System (AIDS) and its variant (the Linear Approximation of AIDS (LA/AIDS)) have been used extensively to model demand systems. Deaton and Muellbauer arrived at the AIDS model by using PIGLOG preferences ordering, which allows perfect aggregation over consumers, via the cost (or expenditure) function. The AIDS demand function put forth by them is in form of the budget share of each of the commodities considered in the analysis. Provided the given sets of restrictions hold, the system of equations represents a set of demand functions which add up to total expenditure, are homogenous of degree zero in prices and total expenditures, taken together, satisfy Slutsky symmetry.

Deaton and Muellbauer argue that their model is 'almost ideal' because it satisfies the axioms of choice exactly: (a) it aggregates perfectly over consumers without invoking parallel linear Engel curves; (b) it has a functional form which is consistent with known household-budget data; (c) it is simple to estimate, largely avoiding the need of non-

[5] To determine whether quarterly estimates of production significantly influenced results, production in each year was also assumed to be constant for each quarter (i.e., estimated quarterly production equaled annual production divided by four). In general, results were relatively invariant to method used for allocating annual production to quarterly estimates.

linear estimation[6]; and (d) it can be used to test the restriction of homogeneity and symmetry through linear restriction on fixed parameters. The authors argue that though the previously existing Rotterdam or translog models include one or more of these properties, none of the existing models possess all of the properties simultaneously. The flexibility of AIDS cost function, in its functional form, allows the demand function derived from it to be first order approximation of any set of demand functions derived from utility maximizing behavior, making AIDS as general as any other flexible form model (e.g., the Rotterdam or translog systems) (Deaton and Muellbauer, 1980).

In its most general form, each equation in the AIDS framework can be expressed as:

$$W_{it} = \alpha_i + \sum_j \gamma_{ij} \ln p_{jt} + \beta_i (\ln X_t - \ln P_t) \qquad (1)$$

where, W_{it} represents the share of the ith good in time period t; p_{jt} represents the price of the jth good in time t ; X_t represents total expenditures on n goods in the system in time period t; $\ln P_t$ is a price index; and α_i, β_i, and γ_{ij} are parameters associated with the system.

Deaton and Muellbaur used a translog price index, which makes the demand system non-linear. To avoid non linearity, the authors suggested that the translog price may be approximated by a Stone price index, given by $\ln P_t = \sum_i W_{it} \ln p_{it}$. However, the Stone index has been shown to cause inconsistent parameter estimates. Moschini(1995)

[6] The authors provide a way of avoiding non linear estimation by using a linear price index in place of the non linear price index used by them, and they suggest the use of Stone's index proposed by Stone (1953). They emphasize, however, that the use of linear price index leads only to an approximation of the system given by using the non linear index.

suggested various other indices which do not have this problem, and this study uses the Corrected Stone Index, used by Asche *et. al.* (1997), which can be written as ln P_t = $\sum_i W_{it} \ln\left(p_{it} / p_i^0\right)$, where p_i^0 is the price at the point of normalization. The corrected Stone Index modifies the model to the Linear Approximation of AIDS (LA/AIDS).

The regularity conditions, implied by budget constraints and utility maximization, impose the following restrictions to the system:

Adding up: $\sum_i \alpha_i = 1$, $\sum_i \gamma_{ij} = 0$, $\sum_i \beta_i = 0$

Homogeneity: $\sum_j \gamma_{ij} = 0$

Symmetry: $\gamma_{ij} = \gamma_{ji}$; $i \neq j$

The adding up condition results in a singular covariance matrix. The system, however, can be estimated by removing one equation from the system. The system is invariant to which equation is dropped, and the parameters of the dropped equation may be retrieved by using the adding up conditions (Asche *et. al.,* 1997).

Based on the theoretical discussion, each equation in the LA/AIDS system representing US and EU shrimp import demand can be written as:[7]

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[7] As indicated, the AIDS model rather than an inverse AIDS model is used to estimate U.S. and E.U. import demand. There is little question that such a specification is appropriate for the Asian and South American product since alternative markets exist for these products. With respect to Central American, produced product can either be exported (almost entirely to the United States) or consumed in the home market which provides at least some justification for AIDS specification. However, additional research may consider a mixed model where the quantity of the Central American product is considered fixed (little is known with respect to the cold-water shrimp in the European market).

$$W_{it} = \alpha_i + \sum_j \gamma_{ij} \ln p_{jt} + \beta_i (\ln X_t - \ln P_t) + \sum_{i=1}^{3} \delta_i D_i$$

where D_i = quarterly dummy variable

∀ $D_1 = 1$ for first quarter and 0 otherwise

$D_2 = 1$ for second quarter and 0 otherwise

$D_3 = 1$ for third quarter and 0 otherwise

Since this study uses quarterly data, dummy variables are added to the model to capture quarterly variation in the demand (the fourth quarter is deleted).

Many approaches are found in the literature for calculating the elasticities for LA/AIDS models. The most commonly used approach is to use formulae suggested by Chalfant (1987). Alston *et. al.* (1994) discuss the problems associated with the elasticities of both the full AIDS model and its linear approximation and suggest the use of Chalfant's formulae for linear approximation of AIDS. Edgerton *et. al.* (1996) also suggest that Chalfant's formulae are 'quite reliable'. These are given by Seale and Merchant (2002) as follows:

(a) *Conditional Expenditure Elasticity:*

Conditional Expenditure Elasticity, $\eta = 1 + \beta / W$,

(b) *Marginal Shares*:

Marginal Share, M = $\beta_i + W_i$

(c) *Conditional Own Price Elasticity*:

Own Price Elasticity, $S_{ii} = -1 + (\gamma_{ii} / W_i) + W_i$

(d) *Conditional Cross Price Elasticity:*

Cross Price Elasticity, $S_{ij} = -1 + (\gamma_{ij} / W_i) + W_j, i \neq j$

This study also uses the above to calculate the marginal effects and the various elasticities associated with demand.

4. Results and Discussion:

4.1. US and EU System Estimates:

Table 2 contains the parameter estimates for the US import demand equations using both the iterative three-stage least squares (IT3SLS) and the iterative seemingly unrelated regression (ITSUR) methods. With the exception of own prices, parameters on prices associated each of the equations are, with few exceptions, positive. The IT3SLS estimates suggest that the Asian and Central American shrimp are conditionally expenditure elastic while the South American shrimp is conditionally expenditure inelastic. ITSUR estimates suggest that both the Central and South American shrimp are expenditure inelastic.

Table 2: Parameter estimates for US import demand

	γ		β		λ		δ	
	3sls	**SUR**	**3sls**	**SUR**	**3sls**	**SUR**		
Asia			0.0569 (0.102)	0.0968 (0.052)	0.0067* (0.002)	0.0026* (0.0009)	δ_1= -0.0055 (0.050)	δ_1= 0.0356 (0.027)
Vs Asia	-0.7028* (0.186)	-0.2345* (0.076)					δ_2= - 0.0239 (0.055)	δ_2= - 0.0302 (0.028)
Vs CA	0.1311 (0.070)	0.1841* (0.042)						
Vs SA	0.5716* (0.182)	0.0503 (0.062)					δ_3= 0.0493 (0.027)	δ_3= 0.0650 (0.018)
Central America			0.0094 (0.047)	-0.0472 (0.0351)	-0.0002 (0.0008)	-0.0007 (0.0005)	δ_1= -0.0958* (0.022)	δ_1= -0.1067* (0.018)
Vs Asia	0.1311 (0.070)	0.1841* (0.042)					δ_2= -0.1659* (0.023)	δ_2= -0.1683* (0.018)
Vs CA	-0.2214* (0.045)	-0.1150* (0.036)						
Vs SA	0.0902 (0.077)	-0.0690 (0.038)					δ_3= -0.1224* (0.012)	δ_3= -0.1133* (0.012)
South America			-0.0474 (0.087)	-0.0495 (0.037)	-0.0064* (0.002)	-0.0019* (0.0007)	δ_1= 0.1013* (0.043)	δ_1= 0.0710* (0.020)
Vs Asia	0.5716* (0.182)	0.0503 (0.062)					δ_2= 0.1898* (0.047)	δ_2= 0.1380* (0.021)
Vs CA	0.0902 (0.077)	-0.0691 (0.038)						
Vs SA	-0.6618* (0.212)	0.0187 (0.071)					δ_3= 0.0731* (0.024)	δ_3= 0.0483* (0.014)

γ = coefficient on prices, β = coefficient on expenditure,
λ = coefficient on trend, δ = coefficient on dummies.
* indicates statistically significant at 5% level of significance

Parameter estimates for the EU import demand equations using both the IT3SLS and ITSUR procedures are presented in Table 3. With the exception of South America, the coefficients on the expenditure term are all negative; implying that South American shrimp is conditionally expenditure elastic while the Asian and Rest of the World shrimp is conditionally expenditure inelastic.

Table 3: Parameter estimates for EU import demand

	γ		β		λ		δ	
	3sls	**SUR**	**3sls**	**SUR**	**3sls**	**SUR**	**3sls**	**SUR**
Asia			-0.1121* (0.054)	-0.0527 (0.034)	0.0014* (0.0006)	0.0009 (0.0004)	δ_1= - 0.0085 (0.027)	δ_1= 0.0156 (0.019)
Vs Asia	0.0378 (0.049)	0.0364 (0.029)					δ_2= -0.0457* (0.018)	δ_2= -0.0326* (0.015)
Vs SA	0.0349 (0.040)	0.0611* (0.020)						
Vs ROW	-0.0728* (0.023)	-0.0975* (0.017)					δ_3= - 0.0295 (0.015)	δ_3= - 0.0203 (0.013)
South America			0.2044* (0.038)	0.1430* (0.020)	-0.0030 (0.0004)	-0.00259* (0.0002)	δ_1= 0.0504* (0.018)	δ_1= 0.0247* (0.011)
Vs Asia	0.0349 (0.040)	0.0611* (0.020)					δ_2= 0.0390* (0.012)	δ_2= 0.0249* (0.008)
Vs SA	0.0618 (0.042)	0.0282 (0.021)						
Vs ROW	0.0967* (0.014)	-0.0839* (0.009)					δ_3= 0.0088* (0.010)	δ_3= 0.0014 (0.007)
Rest of the World			-0.0923* (0.030)	-0.0903* (0.023)	0.0016* (0.0004)	0.0016* (0.0003)	δ_1= -0.0418* (0.030)	δ_1= -0.0404* (0.013)
Vs Asia	-0.0728* (0.023)	-0.0975* (0.017)					δ_2= 0.0066 (0.010)	δ_2= 0.0076 (0.009)
Vs SA	0.0967* (0.014)	-0.0839* (0.009)						
Vs ROW	0.1695* (0.016)	0.1815* (0.013)					δ_3= 0.0207* (0.008)	δ_3= 0.0217* (0.008)

γ = coefficient on prices, β = coefficient on expenditure,
λ = coefficient on trend, δ = coefficient on dummies.
* indicates statistically significant at 5% level of significance

4.2. Discussion on Import Demand Elasticities:

Given the ability to redirect exports based on relative prices among the three primary importing regions (i.e., the U.S., Japan, and the EU), it is plausible hypothesis that import prices are not exogenous. The implication of such a hypothesis is that the quantity supplied responds to price. Since supply equations are not estimated, all the elasticites presented herein should be considered partial, as opposed to reduced form, in nature.

Expenditure, own price and cross price elasticities are calculated using Chalfant's and Slutsky's formulae. The marginal shares, expenditure elasticities and own-price elasticities associated with the U.S. and E.U. shrimp import models are presented in Table 4.

All conditional expenditure elasticities for the United States and the European Union are positive. The IT3SLS results suggest that for every 10% increase in total US expenditures on imported shrimp, demand for Asian product will increase by 11.0% while that for South America and Central American product will increase by 7.3% and 9.3%, respectively. The ITSUR results are similar with the exception that they suggest a somewhat lower response for the Central American product.

Table 4 : Expenditure Elasticity, Marginal Share and Own-Price Elasticity for US and EU Imports

Source Region	**Expenditure Elasticity**		**Marginal Share**		**Own-Price Elasticity**	
	3sls	**SUR**	**3sls**	**SUR**	**3sls**	**SUR**
US Imports from:						
Asia	1.106* (0.19)	1.181* (0.09)	0.591* (0.10)	0.630* (0.05)	-1.781* (0.34)	-0.905* (0.143)
South America	0.738 (0.48)	0.726* (0.20)	0.133 (0.08)	0.131* (0.03)	-4.468* (1.16)	-0.715 (0.39)
Central America	0.936* (0.31)	0.684* (0.23)	0.140* (0.04)	0.102* (0.03)	-2.329* (0.30)	-1.619* (0.24)
EU Imports from:						
Asia	0.704* (0.14)	0.860* (0.21)	0.267* (0.05)	0.326* (0.03)	-0.520* (0.13)	-0.524* (0.07)
South America	2.155* (0.21)	1.808* (0.11)	0.381* (0.03)	0.320* (0.02)	-0.473* (0.23)	-0.694* (0.11)
Rest of the World	0.791* (0.06)	0.796* (0.05)	0.351* (0.03)	0.3534* (0.02)	-0.174* (0.03)	-0.147* (0.03)

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

For the European Union , the IT3SLS results suggest that for a 10% increase in total EU expenditures on imported shrimp, demand for South American product will increase by 21.5% while that for Asian and the rest of the world shrimp will increase by 7.0% and 7.9% respectively. The ITSUR results are, in general, similar to those observed using IT3SLS.

Estimated own-price elasticities for all import regions are negative. For the United States, IT3SLS estimates suggest that imported shrimp from all three exporting regions are price elastic with the South American product being the most elastic and Asian shrimp being the least price elastic. When compared to the IT3SLS estimates, the ITSUR elasticity estimates suggest somewhat lower own-price responsiveness. This is particularly the case with respect to South American product. Specifically, the IT3SLS results indicate a large response in quantity demanded of the South American product with respect to a change in own price whereby the ITSUR results suggest only a moderate response. For the European Union, both the IT3SLS and ITSUR estimates indicate the Asian product to be the most price elastic, followed by the rest of the world and South American shrimp, but IT3SLS estimates for own price elasticity of South American shrimp in the European market is statistically insignificant.

Estimated cross-price demand elasticities, by region, are presented in Table 5. All IT3SLS estimates of the cross-price elasiticities for US shrimp imports, by region, are positive, implying that imports from all regions are substitutes for one another. The ITSUR estimates, however, provide mixed results. Specifically, while the South American and Central American product were found to be substitutes for the Asian product under both the IT3SLS and ITSUR methodologies, Central American product was found to be a complement to the South American product under the ITSUR procedure. Similarly, the South American product was found to be a complement to the Central American product. While complementarities among import products appear implausible, the findings associated with the cross-price elasticities should be viewed with caution given the statistical insignificance associated with many of the elasticity estimates.

Table 5: Cross price elasticity for US shrimp imports

Region	Asia		South America		Central America	
	3sls	SUR	3sls	SUR	3sls	SUR
Asia			1.251* (0.34)	0.275* (0.11)	0.395* (0.13)	0.494* (0.07)
South America	3.686* (1.00)	0.812* (0.34)			0.647 (0.42)	-0.231 (0.21)
Central America	1.410* (0.46)	1.764* (0.28)	0.784 (0.51)	-0.280 (0.25)		

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

Most of the estimated cross-price elasticities in the European Union system are positive and statistically significant (Table 6). South American product was found to be a substitute for the Asian product and vice versa. The relatively small (but positive) estimates suggest that substitutability of the Asian product for South American product (or vice versa) relatively inelastic. The statistical insignificance of Rest of World product with South American product (and vice versa) provides some evidence that these products are not considered substitutes in the EU market.

Table 6: Cross price elasticity for EU shrimp imports

Region	Asia		South America		Rest of the World	
	3sls	SUR	3sls	SUR	3sls	SUR
Asia			0.269* (0.10)	0.338* (0.05)	0.251* (0.06)	0.186* (0.05)
South America	0.576* (0.22)	0.724* (0.11)			-0.103 (0.08)	-0.030 (0.05)
Rest of the World	0.215* (0.05)	0.159* (0.03)	-0.041 (0.03)	-0.012 (0.02)		

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

5. Conclusions:

U.S. and European import demand for shrimp were determined using the Almost Ideal Demand System framework, under iterative three stage least squares (IT3SLS) and iterative seemingly unrelated regression (ITSUR) setup. Resulting parameter estimates were used to determine the marginal shares, expenditure elasticities, own price elasticites and cross price elasticities using Chalfant's formulae.

IT3SLS estimates show that Asian and Central American shrimp are more expenditure elastic and South American shrimp are relatively less expenditure elastic in the US market while for the European market, South American shrimp are highly expenditure elastic while Asian shrimp and shrimp from 'rest of the world' are relatively less expenditure elastic. Own price elasticities of shrimp imported from different regions in both US and EU markets are all negative. In the US market, South American shrimp has the highest own price elasticity, followed by Central American and Asian shrimp. The European market shows relatively smaller effects to own price fluctuations compared to US market. Cross price elasticity estimates for US market suggest that shrimp imported from all the three regions are substitutes of each other. With some notable exceptions, this holds true for the European market too.

In general, a large proportion of the estimated IT3SLS own-price elasticity (four out of the six statistically significant) and an equal proportion of cross-price elasticity (four out of eight statistically significant) estimates are larger than the ITSUR estimates. This agrees, at-least in part, with Whal and Hayes (1990), who observed that Iterative

Seemingly Unrelated Regression results underestimate the elasticities and the estimated elasticities under the Iterative Three Stage Least Square regression framework were more price responsive.

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