International Journal of Food and Agricultural Economics
ISSN 2147-8988, E-ISSN: 2149-3766
Vol. 3 No. 3, Issue, 2015, pp. 31-46

USING ALMOST IDEAL DEMAND SYSTEM TO ANALYZE DEMAND FOR SHRIMP IN US FOOD MARKET

Xia "Vivian" Zhou
Department of Agricultural and Resource Economics, The University of Tennessee, 307-A Morgan Hall, Knoxville, Tennessee 37996, USA, Email: xzhou11@utk.edu

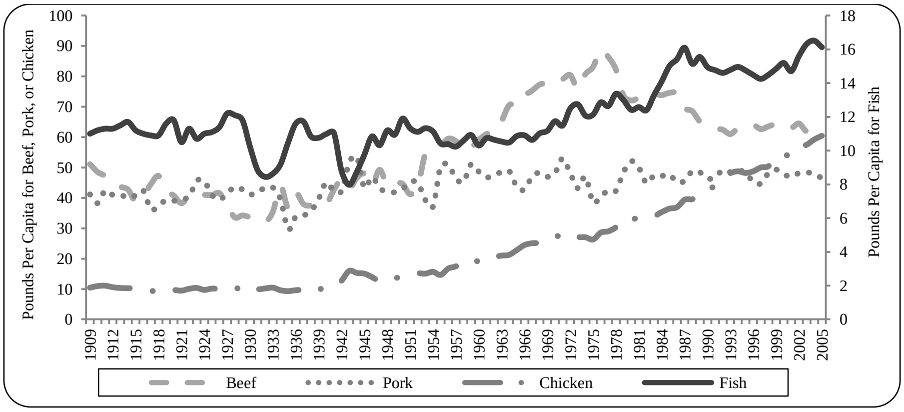
Abstract

This paper analyzes the demand for shrimp along with beef, pork, and chicken in the US food market, which contributes much to predicting supply strategies, consumer preferences and policy making. It focuses on the own and cross elasticity relationship between the expenditure share, price, and expenditure changes. An Almost Ideal Demand System (AIDs) model and two alternative specifications (both nonlinear AIDs and LA-AIDs) are used to estimate a system of expenditure share equations for ocean shrimp, penaeid shrimp, beef, pork, and chicken. Empirical results from nonlinear AIDs model is compared with those from LA-AIDs model. There are quite a few inconsistency between nonlinear and LA results. Results from nonlinear are more expected and more complied with microeconomic theory than those from LA. Also, results indicated that some insignificant slope coefficients and inappropriate signs of them did not comply with microeconomic theory. This could be caused by heteroscedasticity, autocorrelation, a limitation in the data used, or shrimp is a quite different commodity.
Keywords: *Expenditure share, Own and cross relationship, Almost Ideal Demand System (AIDs), Heteroscedasticity, Autocorrelation*

1. Introduction

Most Americans prefer meat (protein) as their primary dishes of meals. Beef, pork, and chicken are the most consumed types of meat and they can be substitute commodities for each other. The per capita consumption pattern of meat (see Figure 1) has changed over the last century due to prices, preferences, and health concerns. Beef consumption increased from 51.1 pounds in 1909 and reached the peak of 88.8 pounds in 1976 and has been declining to 64.9 in 2003 (Haley, 2001; USDA, 2005). Similar trend was indicated for pork – the consumption increased from 41.2 pounds in 1909 and peaked to 53 pounds in 1971 and declined to 42.9 in 1975 and then smoothly rise to 51.7 in 2003 (Davis and Lin, 2005; USDA, 2005). On the contrary the chicken consumption has been an upward trend with 10.4 pounds per capita consumption in 1909 and continued to grow to 60.4 pounds in 2005 (USDA, 2005). Overall fish consumption increased from 11 pounds per capita consumption to 16.1 pounds per capita consumption in 2005 (USDA, 2005). During this time, shrimp has become the most-favored seafood product, desired by U.S. consumers because of its nutritious value, low fat, and delicious taste. Since 1980, U.S. shrimp consumption has grown from 423 million pounds to 1.3 billion pounds in 2001 and per capita consumption of shrimp has increased from 1.5 pounds in 1982 to 3.7 pounds in 2002 (USDOC, 2005). It is expected shrimp will play an even larger role, compared to beef, pork and chicken in the U.S. protein food market with respect to the demand and consumption. The main reasons being -- 1) more and more people prefer low fat, high protein and calcium found in shrimp;

2) a substitute commodity for beef, pork, and chicken in terms of nutrition and health benefits; and 3) convenient for fast food.



Source: United States Department of Agriculture

Figure 1. Per Capita Consumption of Fish, Chicken, Beef, and Pork, U.S., 1909-2005

Since consumers typically consume both red meat and seafood concurrently, an important contribution of this paper would be to examine the demand for shrimp along with beef, pork, and chicken in a system of equation estimation. Furthermore, it is important for producers, wholesalers and policy makers to know own and cross demand elasticities for shrimp, beef, pork and chicken in the U.S. food market in order to predict supply strategies, consumer preferences and guide government to adjust policy on meat industry and trade issues with major shrimp producing countries. Also, people in most developing countries will consume more and more meat as their income increasing or doubling. The US consumption today can be their tomorrow. Thus, to analyze the demand for shrimp along with beef, pork and chicken in domestic market could help US producers to predict international market potential and trade strategy.

Earlier research has examined the demand for red meats using single equation estimation and survey data. Dahlgran (1987) used a Rotterdam demand model to detect elasticity change in beef, pork, and chicken demands by maximum likelihood estimation. The results suggest severe disruption in 1970s and same income and cross-price elasticity but lower own price elasticity in both 1980s and 1960s. However, demand for shrimp or any other seafood was not mentioned at all. Alternative analysis examined the demand for red meat using a system of equation estimation. Heien and Pompelli (1988) used an almost ideal demand system (AIDs) model to study estimates of the economic and demographic effects on the demand for steak, roast, and ground beef. Their results indicate that demand is inelastic for steak and ground beef, elastic for toast and cross-price effects are significance. However, their research only focused on beef without any emphasis on substitute commodities.

Researchers have addressed the demand issues related to the shrimp market, compared to the other food in the U.S. Previous studies typically focused on price determination issues (Doll, 1972; Adams et al., 1987), availability of shrimp (Haby, 2003), and factors affecting consumer choice of shrimp (Houston and Li, 2000). Dey (2000) used a multistage budgeting framework that estimates a demand function for food in the first stage, a demand function for general fish products in the second stage, and a set of demand functions for fish by type in the third stage to result in estimated demand elasticities varying across fish type and across income class. These earlier research on the shrimp industry emphasized the demand for the product using survey data.

Huang and Lin (2000) used the unit value of each food category as variables in modeling a modified Almost Ideal Demand System (AIDs) since the unit values reflect both market prices and consumers' choices of food quality to calculate the quality-adjusted own-price, cross-price, and expenditure elasticities. Also, the AIDs model is estimated to be consistent with a well behaved utility function using US aggregate consumption data (Fisher et al., 2001). However, little research has been conducted to apply the AIDS model toward the study of the own and cross demand relationship between the expenditure shares and price, income changes among the four food categories of shrimp, beef, pork and chicken in the U.S.

This paper used the Almost Ideal Demand System (AIDs) model to estimate a system of expenditure share equations for shrimp, beef, pork, and chicken. There are two categories of shrimp commodities: ocean and penaeid. Totally five equation systems are estimated. Both nonlinear AIDs and LA-AIDs (the Linear Approximation of AIDs) models are used to do the estimations respectively. There are quite a few inconsistency between the results from nonlinear and LA after comparison. Results from nonlinear AIDs are more expected and complied with the microeconomic theory than those from LA-AIDs. It has been used of U.S. aggregate annual data obtained from Bureau of Labor Statistics, Bureau of Economic Analysis, US Census Bureau, and United States Department of Agriculture (USDA) for the period of 1970-2006.

2. Theoretical Model

The Almost Ideal Demand System (AIDS) model of Deaton and Muellbauer (1980) was adopted in this demand analysis. A cost function as suggested by Deaton and Muellbauer was applied and by Shepard's lemma, a modified version of an AIDS model was derived, in which expenditure share of a food category is a function of prices and the related food expenditures as:

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln(X/P) + \lambda_i \, year \tag{1}$$

where w_i is the expenditure share associated with beef, pork, chicken, ocean shrimp, and penaeid shrimp; p_j is the retail price on beef, pork, chicken, ocean shrimp, and penaeid shrimp; α_i is the constant coefficient of the share equation for beef, pork, chicken, ocean shrimp, and penaeid shrimp respectively; γ_{ij} is the slope coefficient associated with the beef, pork, chicken, ocean shrimp and penaeid shrimp in each share equation; λ_i is the slope coefficient of the year for each observation; X is the total nominal expenditure per capita on the system of the five goods given by

$$X = \sum_{i=1}^{n} p_i q_i \tag{2}$$

in which q_i is the quantity demanded for beef, pork, chicken, ocean shrimp, and penaeid shrimp respectively and p_i is the retail price for each of the five commodities respectively; and P is the price index. P is defined as two different ways which come into nonlinear AIDs and LA-AIDs models. First, the nonlinear AIDS model is defined as equation (1) aforementioned with P expressed as:

$$\ln P = \alpha_0 + \sum_{i=1}^{n} \ln p_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \gamma_{ij} \ln p_i \ln p_j \tag{3}$$

The first order conditions can be derived for the cost function or the expenditure share function for beef, pork, chicken, ocean shrimp, and penaeid shrimp respectively and the nonlinear price index function. Second, a linear approximation of the nonlinear AIDS model also suggested by Deaton and Muellbauer (1980) is specified as equation (1) aforementioned with P expressed as:

$$\ln P = \sum_{i=1}^{n} w_i \ln p_i \tag{4}$$

A linear price index and the expenditure share functions give rise to the linear approximate AIDS (LA-AIDS) model. In practice, the LA-AIDS model is more frequently estimated than the nonlinear AIDS model.

Restrictions of homogeneity and symmetry are imposed on the parameters in the above AIDS model:

$$\sum_{i=1}^{n} \alpha_i = 1, \quad \sum_{i=1}^{n} \beta_i = 0, \quad and \sum_{i=1}^{n} \gamma_{ij} = 0 \tag{5}$$

Homogeneity is satisfied if and only if, for all *i*

$$\sum_{i=1}^{n} \gamma_{ij} = 0 \tag{6}$$

and symmetry is satisfied if

$$\gamma_{ij} = \gamma_{ji} \tag{7}$$

To calculate the elasticity, Asche and Wessells (1997) and Edgerton et al. (1996) suggested formulae for the nonlinear AIDs model estimation. These formulae are specified as follows:

a) Total Expenditure Elasticity:

$$N_i = 1 + \beta_i / w_i \tag{8}$$

b) Uncompensated Price Elasticity:

$$Eij = -\delta ij + (\frac{\gamma ij}{wi}) - (\frac{\beta i}{wi})(\alpha j + \sum_{j=1}^{n} \gamma ij \ln pj) \tag{9}$$

when $\delta ij = 1$ for i = j and $\delta ij = 0$ for i ≠ j.

c) Compensated Price Elasticity:

$$E_{ij}^{c} = E_{ij} + w_j N_i \tag{10}$$

Also, elasticity formulae for LA-AIDs model estimation come from Green and Alston (1991). They are defined as follows in matrix:

a) Total Expenditure Elasticity:

$$N = (I + BC)^{-1}B + l \quad (11)$$

where N is the total expenditure elasticity vector; B is a 5-vector with elements $b_i = \beta_i/w_i$; C' is a 5-vector with elements $C_j = w_j\ lnp_j$; I is an identity matrix; and l is a 5-vector with each element equal to 1.

b) Uncompensated Price Elasticity of Demand:

$$E = [I + BC]^{-1}[A + I] - I \quad (12)$$

where E is the 5 by 5 uncompensated price elasticity matrix; A is a 5 by 5 matrix with elements $aij = -\delta ij + [\gamma_{ij} - \beta_i w_j]/w_i$ (when $\delta ij = 1$ for i = j and $\delta ij = 0$ for $i \neq j$).

c) Compensated Price Elasticity of Demand:

$$E^c = E + NW' \quad (13)$$

where E^c is the 5 by 5 compensated elasticity vector; and W is a 5-vector with each element w_i, the expenditure share associated with beef, pork, chicken, ocean shrimp, and penaeid shrimp.

This study uses both models of nonlinear AIDs and LA-AIDs to do the estimation and calculates the mean values of the uncompensated price elasticity, the compensated price elasticity, and the expenditure elasticity respectively for nonlinear AIDs and LA-AIDs by the above formulae, the average expenditure share, the average logarithm price of each commodity and the average real total expenditure.

3. Data and Method

We used 37 years of annual time series data from 1970 to 2006. The price on beef, pork, and chicken were obtained from the United States Department of Agriculture (USDA). The price on both ocean shrimp and penaeid shrimp was replaced by the unit value calculated from dividing the landing value by the output for ocean and penaeid, respectively. The data on the landing value and output of ocean and penaeid shrimp were obtained from NOAA Fisheries service. The aggregate consumption for each of ocean shrimp, penaeid shrimp, beef, pork, and chicken was replaced by each aggregate output of the five commodities, respectively. The nominal expenditure per capita of each commodity in the US was calculated as the aggregate consumption of each multiplied by the price and then divided by the US national population. The total nominal expenditure per capita was calculated by summing the nominal expenditure per capita of each of the five commodities. The expenditure share associated with each commodity (Figure 2) was obtained by the nominal expenditure per capita for each commodity divided by the total nominal expenditure per capita. The US national population was obtained from the US Census Bureau.

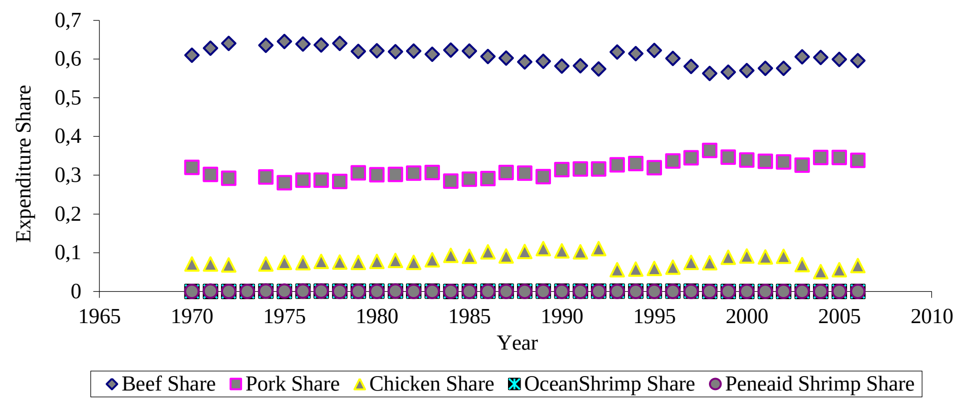


Figure 2. Expenditure Share Plots for Beef, Pork, Chicken, Ocean Shrimp, and Penaeid Shrimp

Seen from Figure 2, beef expenditure share accounts for the largest percentage and goes smoothly around approximately 60% from 1965 to 2006; pork share accounts for the second largest percentage and also goes smoothly around approximately 30% during the same period; chicken share account for the third largest percentage and goes around approximately 10% during the period; and both ocean and penaeid shrimp accounts for a very small portion of the total expenditure. Also, a statistics summary for the dependent variable of the expenditure shares and the independent variables such as natural logarithm of mean scaled prices and the total expenditure per capita are reported in Table 1.

Table 1. Summary Statistics of the Commodity Shares, Prices and Expenditure

Variable	N	Mean	Std. dev	Min.	Max.
Expenditure Shares					
Beef	37	0.604138	0.025833	0.533341	0.644566
Pork	37	0.312693	0.023569	0.259159	0.363493
Chicken	37	0.082941	0.026220	0.051077	0.207212
Ocean shrimp	37	0.000161	0.000107	0.000032	0.000499
Penaeid shrimp	37	0.000067	0.000075	0.000000	0.000358
Natural logarithm of mean scaled price					
Beef	37	-0.060228	0.368489	-0.915721	0.493652
Pork	37	-0.058920	0.369070	-1.007776	0.390737
Chicken	37	-0.065332	0.354330	-0.630188	1.051942
Ocean shrimp	37	-0.105383	0.492165	-1.171869	0.624854
Penaeid shrimp	37	-0.508594	1.247953	-3.232578	1.127738
Natural logarithm of norminal total expenditure per capita	37	10.544439	0.322265	9.761370	10.978650
Natural logarithm of linear stone price index	37	-0.050855	0.332591	-0.879022	0.399364
Natural logarithm of real total expenditure for LA-AIDs	37	10.595295	0.044780	10.414790	10.661452

In the above expenditure share equation system, each price observation of each commodity is divided by its price mean to get mean-scaled price data (Goodwin, 2008) and then is taken in natural log. Since the expenditure shares sum to 1 in the equation system, one of the share equations is deleted to avoid the singularity and whichever one is eliminated does not have any impact on the results (Goodwin, 2008). Thus, chicken expenditure share equation is deleted and the parameters associated with the chicken share equation can be calculated by the restrictions of both homogeneity and symmetry. Therefore the constant coefficient in the chicken share equation can be obtained by subtracting the summation of the other four constant coefficients from one. Similarly, the slope coefficient in the chicken share equation can be calculated by subtracting the summation of the other four slope coefficients from zero.

The nonlinear AIDs model was estimated by applying the MODEL procedure and the econometric method of ITSUR (iterated seemingly unrelated regression) in SAS computer program (Goodwin, 2008). The LA-AIDs model was estimated by applying the SYSLIN procedure and the econometric method of ITSUR (Goodwin, 2008) in SAS computer program, too. The parametric constraints of homogeneity and symmetry conditions were imposed.

Once the AIDs model was estimated, the mean values of the uncompensated demand elasticity, the compensated demand elasticity, and the expenditure elasticity would be calculated for nonlinear AIDs and LA-AIDs estimates, respectively by the formulae mentioned in the section of Theoretical Model, the average expenditure share, the average logarithm price of each commodity, and the average real total expenditure.

4. Results

Table 2 presents the R^2 for the system of equations from both nonlinear AIDs and LA-AIDs estimation. Most of the R^2s or adjusted R^2s are reasonable except the R^2 for the ocean shrimp share equation from the nonlinear AIDs is extremely low to 6 or 7 percent in magnitude. The reason could be the ocean shrimp accounts for a small percentage of the total expenditure or data limitation. The system weighted R^2 from LA-AIDs is much higher than those from nonlinear AIDs. The reason could be different estimate procedure: SYSLIN procedure is used in LA estimation and MODEL procedure is used in nonlinear estimation.

Table 2. R^2 of ITSUR Estimation from Nonlinear AIDs and LA-AIDs Estimation

	Nonlinear AIDs					LA-AIDs
	Beef Share	Pork Share	Chicken Share	Ocean Shrimp Share	Penaeid Shrimp Share	System Weighted R^2
R^2	0.6643	0.7877	-	0.0627	0.4092	0.8962
Adj. R^2	0.6163	0.7574	-	-0.0712	0.3248	

Table 3 presents the parameter estimates and associated standard error and P value of the expenditure share function systems from nonlinear AIDs model and LA-AIDs model, respectively. For the beef share equation, both nonlinear and LA intercept estimates are positive and significant. The total expenditure coefficient estimate from nonlinear is negative and significant, but the expenditure coefficient estimate from LA is positive and insignificant. This implies that as the real total expenditure increases, nonlinear estimate shows the beef expenditure share would decrease but the LA estimate shows the beef share would not be correlated to the total expenditure. Both nonlinear and LA beef own price coefficient estimates are significant. The nonlinear beef own price coefficient estimate is negative as expected due to the downward own-price-demand curve theory, but the LA estimate is positive. Also, the magnitude from LA estimate is much lower than that from the nonlinear estimate. The reason could be correlation or data limitation.

Table 3. ITSUR Parameter Estimates from the Nonlinear AIDs and LA-AIDs Models

	Nonlinear AIDs			LA-AIDs		
	Estimate	Std. Error	P-Value	Estimate	Std. Error	P-Value
α_b	8.14580 *	0.94620	<.0001	6.98378 *	1.27278	<.0001
α_p	-0.06631	0.77480	0.93230	-1.96659	0.99411	0.05750
α_c	-7.08322 *	0.54040	<.0001	-4.01684		
α_{so}	-0.00266	0.00697	0.70470	0.00624	0.01033	0.55020
α_{sp}	0.00641	0.00457	0.17130	-0.00659	0.00699	0.35330
β_b	-0.08456 *	0.01150	<.0001	0.06476	0.06494	0.32690
β_p	0.00444	0.00942	0.64110	0.07933	0.04821	0.11070
β_c	0.08003			-0.14415		
β_{so}	0.00005	0.00009	0.55870	-0.00027	0.00041	0.51730
β_{sp}	0.00004	0.00009	0.62800	0.00032	0.00027	0.23900
γ_{bb}	-0.58262 *	0.14860	0.00050	0.05458 *	0.02321	0.02570
γ_{bp}	0.01679	0.07960	0.83440	-0.00191	0.01968	0.92330
γ_{bc}	0.55926 *	0.07560	<.0001	-0.05224 *	0.00838	<.0001
γ_{bso}	0.00012	0.00064	0.84930	-0.00029 *	0.00017	0.09890
γ_{bsp}	0.00645 *	0.00267	0.02210	-0.00014	0.00012	0.24950
γ_{pp}	0.04480 *	0.02560	0.09000	0.02516	0.01984	0.21490
γ_{pc}	-0.06821	0.06340	0.29000	-0.02348 *	0.00665	0.00140
γ_{pso}	0.00018	0.00010	0.08770	0.00009	0.00019	0.63100
γ_{psp}	0.00104	0.00193	0.59400	0.00014	0.00013	0.28720
γ_{cc}	-0.44396 *	0.03170	<.0001	0.07566		
γ_{cso}	-0.00031	0.00063	0.62480	0.00004	0.00007	0.58320
γ_{csp}	-0.04678 *	0.01780	0.01340	0.00002	0.00004	0.58920
γ_{soso}	0.00002	0.00002	0.38830	0.00013 *	0.00004	0.00500
γ_{sosp}	-0.00001	0.00001	0.58190	0.00003 *	0.00002	0.09540
γ_{spsp}	0.03930 *	0.01690	0.02660	-0.00006 *	0.00002	0.00090
λ_b	-0.00334 *	0.00045	<.0001	-0.00355 *	0.00045	<.0001
λ_p	0.00017	0.00034	0.62710	0.00072 *	0.00035	0.04590
λ_c	0.00318			0.00283		
λ_{soso}	0.00000	0.00000	0.74670	0.00000	0.00000	0.66900
λ_{sosp}	0.00000	0.00000	0.15980	0.00000	0.00000	0.54000

Note: * denotes significance at the 0.10 level, based on asymptotic t-ratios.

Both nonlinear and LA chicken price coefficient estimates are significant; the nonlinear estimate is positive as expected, which implies that beef and chicken are strong substitute commodities, but the LA estimate is negative; and the magnitude from LA estimate is much lower than that from the nonlinear estimate, too. Correlation or data limitation might be the reason to this difference or inconsistency, too. The pork price coefficient estimates have a positive sign for nonlinear and negative sign for LA, and both are insignificant, which is inconsistent with substitute commodity theory. Also, the magnitude from nonlinear is much higher than that from LA. The reason could be beef and pork is not strong substitute commodities, correlation or limited data constraints. Both nonlinear and LA ocean shrimp price coefficient estimates are positive as expected, but nonlinear estimate is insignificant and LA estimate is significant. Also, both estimates are small in magnitude. These might be due to the small percentage of ocean shrimp expenditure share or data limitation. The same issues happen to the penaeid shrimp price coefficient estimate.

For the pork share equation, the total expenditure coefficient estimates from both nonlinear and LA are positive and insignificant. The insignificancy shows the pork share is uncorrelated with the real total expenditure. This implies that the pork share would not change as the real total expenditure change. Both nonlinear and LA pork own price coefficient estimates are positive, which is contradictory to the downward own-price-demand curve theory and indicates by theory that pork could be a Giffen good in the US market from 1970 to 2006. However, pork is not a Giffen good in the real market. The reason could be correlation or data limitation. Beef price coefficient estimates are the same situation as the pork price coefficient estimates in the beef share equation due to the symmetry. The chicken price coefficient estimates from both nonlinear and LA is negative, and nonlinear estimate is insignificant but LA is significant. This indicates that pork and chicken might be weak complements in the US market from 1970 to 2006. The Ocean shrimp price coefficient estimates from both nonlinear and LA is positive, and the nonlinear estimate is significant but the LA is insignificant. The positive sign is consistent with the substitute commodity theory. The penaeid shrimp price coefficient estimates from both nonlinear and LA is positive, too but insignificant.

For the chicken share equation, the coefficient estimates of the real total expenditure and the LA own price are calculated from symmetry and homogeneity already mentioned in the section of Data and Method. The real total expenditure coefficient estimate from nonlinear is positive, but the expenditure estimate from LA is negative. This implies that as the real total expenditure increases, nonlinear estimate shows the chicken expenditure share would increase, but the LA estimates shows that the chicken share would decrease. The chicken own price coefficient estimate from nonlinear is negative and significant, which is consistent with the downward own-price-demand curve theory; but the estimate from LA is positive, which is calculated from symmetry and homogeneity. The reason could be different estimations procedures mentioned in the section of Data and Method. The beef price coefficient estimates are the same as the chicken price coefficient estimates in the beef share equation due to the symmetry. Likely, the pork price coefficient estimates are the same as the chicken price coefficient in the pork share equation due to the symmetry. Also, the ocean shrimp price coefficient estimates are the same as the chicken price coefficient estimates in the ocean shrimp share equation and the penaeid shrimp price coefficient estimates are the same as the chicken price coefficient estimates in the penaeid shrimp share equation, which will be discussed as follows.

For the ocean shrimp share equation, the total expenditure coefficient estimate from nonlinear is positive, but the estimate from LA is negative. Both estimates are insignificant and small in magnitude. The ocean shrimp own price coefficient estimates from both nonlinear and LA are positive and small in magnitude. The estimate from nonlinear is insignificant, but the estimate from LA is significant. The positive sign is contradictory to the downward own-price-demand curve theory. The reason could be correlation or data limitation. The beef price coefficient estimates and pork price coefficients estimates are the same as those in the beef share equation and pork share equation due to the symmetry. The chicken price coefficient estimate from nonlinear is negative, but estimate from LA is positive. Both estimates are insignificant and small to the fourth or fifth decimal digit in magnitude. Both nonlinear and LA pork price coefficient estimates are positive and small to the fourth or fifth decimal digit in magnitude. The nonlinear estimate is significant, but LA estimate is insignificant. The penaeid shrimp price coefficient estimate from nonlinear is negative and insignificant, but the estimate from LA is positive and significant. Estimates from both nonlinear and LA are small to the fifth decimal digit in magnitude.

For the penaeid shrimp share equation, the total expenditure coefficient estimates from both nonlinear and LA are positive, insignificant, and small to the fourth or fifth decimal digits. The penaeid shrimp own price coefficient estimate from nonlinear is positive which is contradictory to the downward own-price-demand curve theory; but the estimate from LA is negative and much smaller than nonlinear estimate in magnitude. Both own price coefficient estimates are significant. The beef price coefficient estimates and pork price coefficients estimates are the same as those in the beef share equation and pork share equation due to the symmetry. The chicken price coefficient estimate from nonlinear is negative and significant, but the estimate from LA is positive and insignificant. LA estimate is much lower than nonlinear estimate in magnitude. The ocean shrimp price coefficient estimates are the same as the penaeid shrimp price coefficients in the ocean shrimp share equation due to the symmetry.

The year trend coefficient estimates from both nonlinear and LA are consistent. The year estimates from share equations of pork, chicken, ocean shrimp, and penaeid shrimp are positive, insignificant, and small to third or fifth decimal digits in magnitude. This implies that time trend is not correlated to the expenditure share. Estimates of beef share equations from both nonlinear and LA are negative and significant, which indicates that as time goes by, beef share would be decreased little by little.

In comparison, there are quite a few differences for the coefficient estimates of total expenditure and price between nonlinear AIDs and LA-AIDs in terms of sign, magnitude, and statistical significance (Figures 3 and 4). The reason could be different estimate procedure: MODEL procedure for nonlinear AIDs and the SYSLIN procedure for LA-AIDs or some other reasons that need to be further studied.

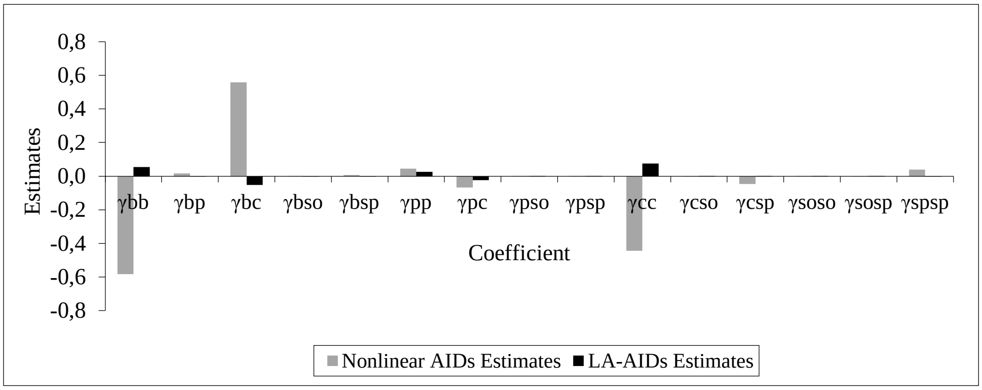


Figure 3. Compare Price Coefficient Estimates from Nonlinear AIDs and LA-AIDs

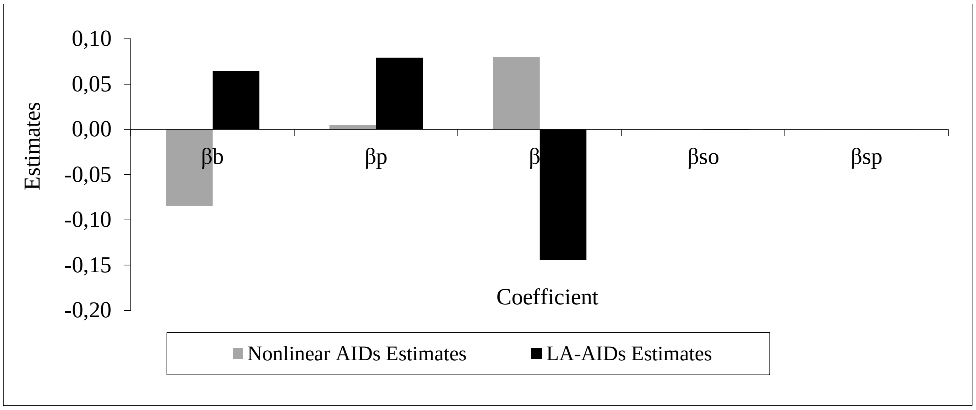


Figure 4. Compare Total Expenditure Coefficient Estimates from Nonlinear AIDs and LA-AIDs

Given the coefficient estimates of total expenditure and prices, the mean values of expenditure elasticity, uncompensated demand elasticity, and compensated demand elasticity were calculated by the formulae mentioned in the section of Data and Method. Tables 4, 5, and 6 present these results. Seen from Table 4 and Figure 5, the mean values of beef and pork expenditure elasticity from nonlinear AIDs is slightly smaller than that from LA; the mean value of beef expenditure elasticity is close to 1 from LA and nonlinear, so is the mean value of pork. This indicates that a 1 percent increase in the total expenditure would induce an approximately 1 percent increase in quantity demanded for both beef and pork. However, the mean values of chicken, ocean and penaeid shrimp expenditure elasticity from nonlinear are much higher than that from LA. Their mean values of expenditure elasticity from nonlinear are greater than 1, which implies that a 1 percent increase in total expenditure would induce more than 1 percent increase in the quantity demanded for the three commodities; but the mean values of chicken and ocean shrimp expenditure elasticity from LA is less than 1, which implies that that a 1 percent increase in total expenditure would induce less than 1 percent increase in the quantity demanded. Therefore, the mean values of beef and pork expenditure elasticity from nonlinear are consistent with those from LA; but the mean values of chicken, ocean shrimp, and penaeid shrimp elasticity from nonlinear are inconsistent with those from LA: nonlinear shows more sensitive consumer demand to expenditure, but LA shows much less sensitive consumer demand to expenditure. In general, the consumption for each of the five goods would increase by approximately 1 percent as the real total expenditure increase by 1 percent.

Table 4. Mean Values of Expenditure Elasticity from both LA-AIDs and Nonlinear AIDs Models

Expenditure Elasticity		
	LA - AIDs	Nonlinear AIDs
Beef	1.05303	0.8600261
Pork	1.06496	1.0141908
Chicken	0.88196	1.9649423
Ocean Shrimp	0.99978	1.3231964
Penaeid Shrimp	1.00026	1.6376027

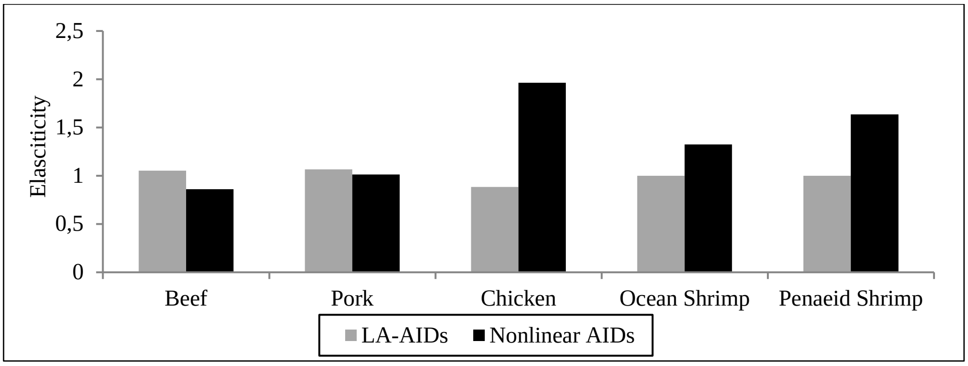


Figure 5. Compare Mean Values of Expenditure Elasticity from LA-AIDs and Nonlinear AIDs

Table 5 and Figure 6 present the mean values of uncompensated demand elasticity matrix from both LA-AIDs and nonlinear AIDs model. The mean values of estimated own-price elasticities from LA-AIDs are negative for the five commodities, which is consistent to downward own-price demand curve theory. The magnitude is less than 1 except for the penaeid shrimp. The magnitude for beef and pork is close to 1 and magnitude for chicken and ocean shrimp is close to 0.1 and 0.3, which implies consumer's demand for beef and pork is much more responsive with respective to price than for chicken and ocean shrimp. The highest magnitude is 1.7 for penaeid shrimp. This indicates that among the five commodities, consumer's demand for penaeid shrimp is the most responsive with respect to its own price. The mean values of estimated cross-price elasticity from LA-AIDs are not symmetric in terms of sign. This is implausible probably due to the statistical insignificance. The negative sign implies complementary commodities for beef-pork, beef-chicken, beef-ocean shrimp, etc., and the positive sign implies the substitute commodities for the rest pairs.

Table 5. Mean Values of Uncompensated Demand Elasticity from both LA-AIDs and Nonlinear AIDs Models

	Beef	Pork	Chicken	Ocean Shrimp	Penaeid Shrimp
LA -AIDs					
Beef	-0.97905	-0.03004	-0.07809	-0.00041	-0.00020
Pork	-0.13052	-0.99908	-0.07872	0.00021	0.00035
Chicken	0.34403	0.21318	-0.13496	0.00059	0.00033
Ocean Shrimp	-0.64939	0.91320	0.30398	-0.34467	0.17411
Penaeid Shrimp	-4.11768	0.47919	-0.03427	0.41711	-1.73746
Nonlinear AIDs					
Beef	-1.75473	0.06500	0.81893	0.00015	0.01061
Pork	0.03245	-0.86051	-0.20731	0.00057	0.00334
Chicken	5.29764	-1.07887	-5.61669	-0.00337	-0.56367
Ocean Shrimp	0.28608	1.01410	-1.69173	-0.88250	-0.04914
Penaeid Shrimp	95.74295	15.45459	-701.41280	-0.11803	588.69572

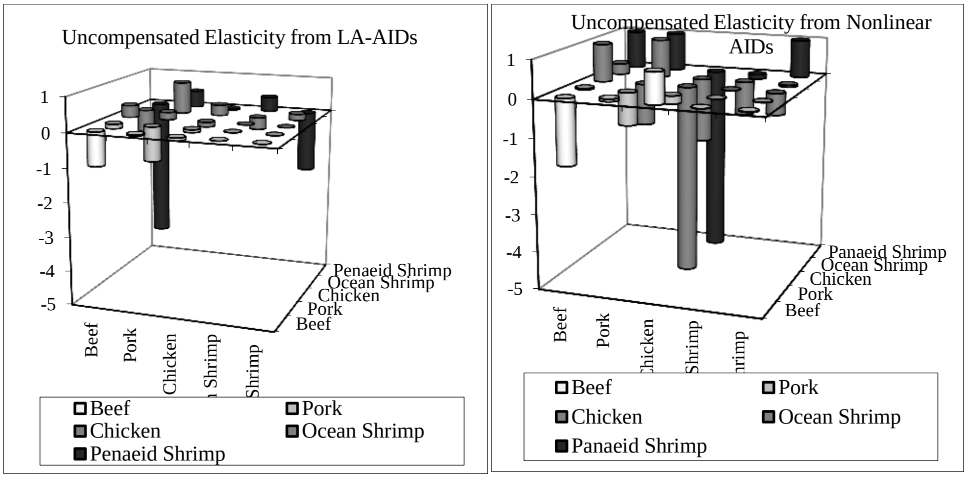


Figure 6. Mean Values of Uncompensated Elasticity from LA-AIDs and Nonlinear AIDs, respectively

The mean values of the estimated own price elasticity from nonlinear are negative except penaeid shrimp. Also, the magnitude for penaeid shrimp is unreasonably high. The reason could be data limitation or statistical insignificance. The highest magnitude implies that consumer's demand for penaeid shrimp is the most sensitive to its own price among the five commodities. Chicken own price elasticity is the highest in magnitude except penaeid shrimp, beef is the second highest, ocean shrimp is the third, and pork follows closely. The mean values of estimated cross-price elasticity from nonlinear are symmetric in terms of sign. The positive sign indicates the substitute commodity pairs which are beef-pork, beef-chicken, beef-ocean shrimp, beef-penaeid shrimp, pork-ocean shrimp, and pork penaeid shrimp. Also, the negative sign indicates the complementary commodity pairs which are the rest.

In comparison, the mean values of the uncompensated demand elasticity from LA-AIDs estimates are consistent with those from nonlinear in terms of the negative sign of the own-price elasticity except penaeid shrimp. However, both are inconsistent in terms of cross-price elasticity. The mean values of the uncompensated cross-price elasticities from nonlinear are symmetric in terms of sign, which is reasonable; but the mean values of the uncompensated cross-price elasticity from LA are not symmetric in terms of sign, which is unreasonable. The reason could be the different estimation procedure or statistical insignificance.

Table 6 and Figure 7 present mean values of compensated demand elasticity from LA-AIDs and nonlinear AIDs respectively. For the mean values of compensated elasticity from LA-AIDs, all the mean values of own-price elasticity are negative, but ocean shrimp and penaeid shrimp are unreasonably large in magnitude. Most of the mean values of cross-price elasticity from LA-AIDs are symmetric in terms of sign except that chicken-beef is positive, but beef-chicken is negative. Also, ocean shrimp pairs and penaeid shrimp pairs are unreasonably high in magnitude. The reason could be the small percentage expenditure share. For the mean values of compensated elasticity from nonlinear AIDs, all the mean values of own-price elasticity are negative and reasonable in magnitude except penaeid shrimp is positive and unreasonable in magnitude. All the mean values of cross-price elasticity from nonlinear AIDs are symmetric in terms of sign. Three pairs such as penaeid shrimp-beef, penaeid shrimp-chicken, and penaeid shrimp own are unreasonably high in magnitude.

Table 6. Mean Values of Compensated Demand Elasticity from LA-AIDs and Nonlinear AIDs models, respectively

	Beef	Pork	Chicken	Ocean Shrimp	Penaeid Shrimp
LA - AIDs					
Beef	-2.01643	0.26297	-0.04632	-0.00051	-0.00026
Pork	0.18674	-3.88243	-0.16882	0.00084	0.00119
Chicken	4.75205	2.88303	-2.54425	0.00731	0.00407
Ocean Shrimp	-4058.08142	5707.78189	1899.96140	-2155.17641	1088.16173
Penaeid Shrimp	-61780.7542	7190.03274	-514.17362	6258.25260	-26069.68681
Nonlinear AIDs					
Beef	-1.23515	0.33392	0.89027	0.00029	0.01067
Pork	0.64516	-0.54339	-0.12319	0.00073	0.00340
Chicken	6.48474	-0.46445	-5.45371	-0.00305	-0.56354
Ocean Shrimp	1.08548	1.42785	-1.58198	-0.88229	-0.04906
Penaeid Shrimp	96.73230	15.96665	-701.27700	-0.11776	588.69583

By comparison of results from LA-AIDs and nonlinear AIDs, there are quite a few differences between them. Results from nonlinear AIDs are more expected and more complied with microeconomic theory than those from LA-AIDs. For example, the mean values of uncompensated and compensated elasticities from nonlinear AIDs are symmetric, but those from LA-AIDs are not symmetric; the nonlinear beef own price coefficient estimate is negative as expected due to the downward own-price-demand curve theory, but the LA estimate is positive; and the magnitude from LA estimate is much lower than that from the nonlinear estimate.

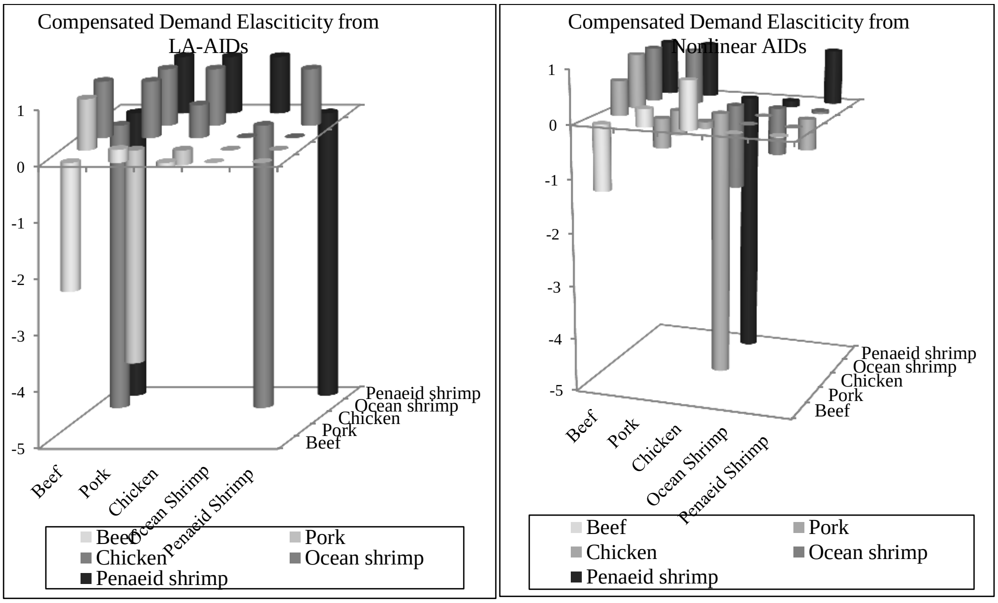


Figure 7. Mean Values of Compensated Elasticity from LA-AIDs and Nonlinear AIDs, respectively

5. Conclusions

This paper uses both models of nonlinear AIDs and LA-AIDs to examine the demand system analysis of beef, pork, chicken, ocean shrimp, and penaeid shrimp in the U.S. food market, especially focusing on the own and cross relationship between the expenditure share and price, expenditure changes from the above five food commodities. Mean Values of the expenditure elasticity, compensated and uncompensated elasticity are calculated to imply the consumer's demand responsiveness with respective to the change of the expenditure, own price, and cross price. These results contribute much to predicting supply strategies, consumer preferences and policy making.

Results from nonlinear AIDs model is compared with those from LA-AIDs model. There are quite a few inconsistency between nonlinear and LA results. Results from nonlinear are more expected and more complied with microeconomic theory than those from LA. Further study needs to be conducted on whether nonlinear AIDs model is more valid than LA-AIDs in the application of food demand analysis.

Empirical results indicated that some insignificant slope coefficients and inappropriate signs of them did not comply with microeconomic theory. This could be caused by heteroscedasticity, autocorrelation, a limitation in the data used, too few years of data or shrimp is a commodity that is quite different. Further investigation into our data and demand elasticities is being conducted.

6. References

Adams, C., Prochaska, F. & Spreen, T. (1987). Price determination in the US shrimp market. *Southern Journal of Agricultural Economics* 9, 103-112.

Asche, F. & Wessells, C.R. (1997). On price indices in the Almost Ideal Demand System. *American Journal of Agricultural Economics* 79, 1182-1185.

Dahlgran, R.A. (1987). Complete flexibility systems and the stationarity of U.S. meat demands. *Western Journal of Agricultural Economics* 12 (2), 152-163.

Davis, C. G. and Lin, B. H. (2005). Factors affecting U.S. pork consumption. United States Department of Agriculture, (LDP-M-130-01).

Deaton, A. & Muellbauer J. (1980). An Almost Ideal Demand System. *The American Economic Review* 70, 312 – 326.

Dey, M.M. (2000). Analysis of demand for fish in Bangladesh. *Aquaculture Economics and Management* 4, 65 – 83.

Doll, J. (1972). An econometric analysis of shrimp ex-vessel prices. *American Journal of Agricultural Economics* 54, 431-440.

Edgerton, D.L., Assarsson, B., Hummelmose, A., Laurila, I.P., Rickertsen, K., & Vale, P.H. (1996). The econometrics of demand systems with applications to food demand in the Nordic countries. Kluwer Academic Publishers.

Fisher, D., Fleissig, A.R., & Serletis, A. (2001). An empirical comparison of flexible demand system functional forms. *Journal of Applied Econometrics* 16, 59-80.

Goodwin, B. (2008). SAS/ETS examples: Estimating an Almost Ideal Demand System model. Available at http://support.sas.com/rnd/app/examples/ets/aids/.

Goodwin, B. (2008). SAS/ETS examples: Calculating elasticities in an Almost Ideal Demand System model. Available at http://support.sas.com/rnd/app/examples/ets/elasticity/.

Green, R. & Alston, J.M. (1991). Elasticities in AIDs models: A clarification and extension. *American Journal of Agricultural Economics* 73, 874-875.

Haby, M.G. (2003). Status of the world and U.S. shrimp markets. Trade Adjustment Assistance for Farmers Technical Assistance, United States Department of Agriculture (pp. 7-23).

Haley, M.M. (2001). Changing consumer demand for meat: the U.S. example, 1970-2000. Economic Research Service, United States Department of Agriculture.

Heien, D. & Pompelli, G. (1988). The demand for beef products: cross-section estimation of demographic and economic effects. *Western Journal of Agricultural Economics* 13, 37-44.

Houston, J.E & Li, H.S. (2000). Factors affecting consumer preferences for shrimp in Taiwan. Department of Agricultural and Applied Economics, University of Georgia and Food Industry Research and Development Institute, Taiwan.

Huang, K.S. & Lin, B.H. (2000). Estimation of food demand and nutrient elasticities from household survey data. Economic Research service, U.S. Department of Agriculture, (TB – 1887).

United States Department of Agriculture (USDA). (2005). Livestock & Meat Domestic Data. Available at http://www.ers.usda.gov/data-products/livestock-meat-domestic-data.aspx.

United States Department of Commerce (USDOC). (2005). Per Capita Consumption. Available at http:// http://www.st.nmfs.noaa.gov/st1/fus/fus05/08_perita2005.pdf.