Demand Analysis for Shrimp in the United States

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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 relationship between the expenditure share and price, income changes. An Almost Ideal Demand System (AIDs) model and two alternative specifications are used to estimate a system of expenditure share equations for shrimp, beef, pork, and chicken. 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, or shrimp is a commodity that is quite different.

Keywords: *expenditure share, own and cross relationship, Almost Ideal Demand System (AIDs), heteroscedasticity, and autocorrelation*

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Introduction

Most Americans prefer meat (protein) as their primary dishes of meals. Beef, chicken, and pork 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, preference, 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 the present. Similar trend was indicated for pork – the consumption increased and peaked to 53 pounds in 1971 and declined there after till the present. 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. Overall fish consumption increased from 11 pounds per capita consumption to 16.1 pounds per capita consumption in 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 lb in 1982 to 3.7 lb in 2002 (USDOC). 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.

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, 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 and two alternative specifications to estimate a system of expenditure share equations for shrimp, beef, pork, and chicken. It has been used of U.S. aggregate data obtained from Bureau of Labor Statistics, Bureau of Economic Analysis, and United States Department of Agriculture (USDA) for the period of 1970-2002. The price on beef, chicken and pork were obtained from the USDA. The price on shrimp was replaced by the unit value obtained by dividing the landing value by the output. The data on the landing value and output of shrimp were obtained from NOAA Fisheries service. The aggregate consumption for shrimp, beef, chicken and pork was replaced by the aggregate output of the four food categories. The total disposable income in the U.S. was applied for the total expenditure on the system of goods, which was obtained from Bureau of Labor Statistics. The consumer price index (CPI) was obtained from Bureau of Economic Analysis.

Theoretical Model

The Almost Ideal Demand System (AIDS) model of Deaton and Muellbauer (1980b) was adopted in this demand analysis. A cost function as suggested by Deaton and Muellbauer was applied by replacing unit value for the price of shrimp in the function. By applying Shepard's lemma, we can derive a modified version of an AIDS model, in which expenditure share of a food category is a function of prices and the related food expenditures as

$$(1) \qquad w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln\left(X/P\right)$$

where w_i is the expenditure share associated with beef, chicken, shrimp and pork, p_j is the price on beef, chicken, shrimp and pork, α_i is the constant coefficient for beef, chicken, shrimp and pork share equation, γ_{ij} is the slope coefficient associated with the beef, chicken, shrimp and pork in the share equation X is the total expenditure on the system of goods given by

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

in which q_i is the quantity demanded for beef, chicken, shrimp and pork, p_i is the consumer price index for beef, chicken, shrimp and pork.

The first order conditions or the demand for beef, chicken, shrimp and pork in the nonlinear AIDS model is defined as:

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

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

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Deaton and Muellbauer (1980a) also suggested a linear approximation of the nonlinear AIDS model by specifying a linear price index given by

$$\ln P = \sum_{i=1}^{n} w_i \ln p_i \qquad (4)$$

that gives 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 were imposed on the parameters in the above AIDS model:

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

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

$$\sum_{j=1}^{n} \gamma_{ij} = 0 \quad (6)$$

and symmetry is satisfied if

$$\gamma_{ij} = \gamma_{ji} \quad (7)$$

Data

We used 30 years of annual time series data from 1970 to 2002. The price on beef, chicken and pork were obtained from the United States Department of Agriculture (USDA). The price on shrimp was replaced by the unit value obtained by dividing the landing value by the output. The data on the landing value and output of shrimp were obtained from NOAA Fisheries service. The aggregate consumption for shrimp, beef, chicken and pork was replaced by the aggregate output of the four food categories. The total disposable income in the U.S. was applied for *X* of the total expenditure on the system of goods, which was obtained from Bureau of Labor Statistics. The consumer price index (CPI) was obtained from Bureau of Economic Analysis.

In the above expenditure share equation system, price on beef, chicken and shrimp were divided by the price on pork to be normalized. And then the constant coefficient in pork share equation can be obtained by subtracting the summation of the other three constant coefficients from one. Similarly, the slope coefficient associated with pork can be obtained by subtracting the summation of the other three slope coefficients from zero.

The above AIDs model was estimated by the econometric methods of OLS and GMM in SAS computer programs. The parametric constraints of homogeneity and symmetry conditions were imposed.

Empirical Model and Results

Parameter estimates of the expenditure share function systems for beef, chicken, shrimp and pork are reported in Table 2.

For the beef expenditure share function, the slope coefficient estimate of 0.002871, -0.02893 and 0.010038 for its own price and the price of chicken and shrimp, which has quite insignificant P values of 0.9371, 0.5731 and 0.010038 suggests that the expenditure share of beef is not correlated much to its own price and the price of chicken and shrimp, which is not appropriate. The slope coefficient estimate of -0.16501, which has a significant P value of 0.03 at a level of 0.05 implies that the expenditure share of beef is negatively correlated to the disposable income. The time slope coefficient estimate of -0.00183, which has an insignificant P value of 0.2166 at a level of 0.05 implies that the expenditure share of beef is not correlated much to time.

For the chicken expenditure share function, the slope coefficient estimate of 0.088545 and -0.0348 for its own price and the price of beef, which has quite significant P values of 0.0005 and 0.0392 at the 0.05 level, suggests that the expenditure share of chicken is positively correlated much to its own price and negatively correlated to the price of beef. However, the estimate of -0.00835, which has an insignificant value of 0.2008 at the 0.05 level suggests that it is not correlated much to the price of shrimp. The slope coefficient estimate of 0.071705 and 0.003476 for the disposable income and time, which has significant P values of 0.0338 and 0.003476 at the 0.05 level, implies that the expenditure share of chicken is positively correlated to the disposable income and time.

For the shrimp expenditure share function, the slope coefficient estimate of 0.003598 and -0.00454 for its own price and the price of beef, which has quite significant P values of less than 0.0001 and 0.0029 at the 0.05 level, suggests that the expenditure share of shrimp is positively correlated much to its own price and negatively correlated to the price of beef. However, the estimate of 0.001055, which has an insignificant value of 0.5931 at the 0.05 level, suggests that it is not correlated much to the price of chicken, same as the above chicken expenditure share function estimates. The slope coefficient estimate of -0.00397 and 1.46E-06 for the disposable income and time, which has insignificant P values of 0.1631 and 0.9792 at the 0.05 level, implies that the expenditure share of chicken is not correlated to both disposable income and time.

Since price on beef, chicken and shrimp were divided by the price on pork to be normalized as mentioned in the section of DATA, the intercept coefficient in the pork share equation can be obtained by subtracting the summation of the other three intercept coefficients from one and the slope coefficient associated with pork can be obtained by subtracting the summation of the other three slope coefficients from zero.

Conclusions

This paper examines the demand system analysis of shrimp, beef, pork and chicken in the U.S. food market, especially focusing on the own and cross relationship between the expenditure share and price, income changes from the above four food categories, which contributes much to predicting supply strategies, consumer preferences and policy making.

The popular AIDs model was applied and the expenditure share equation system of its modified version was estimated. The US aggregate consumption data for the above four commodities was replaced by their total outputs. The price of shrimp was replaced by its unit value.

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.

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

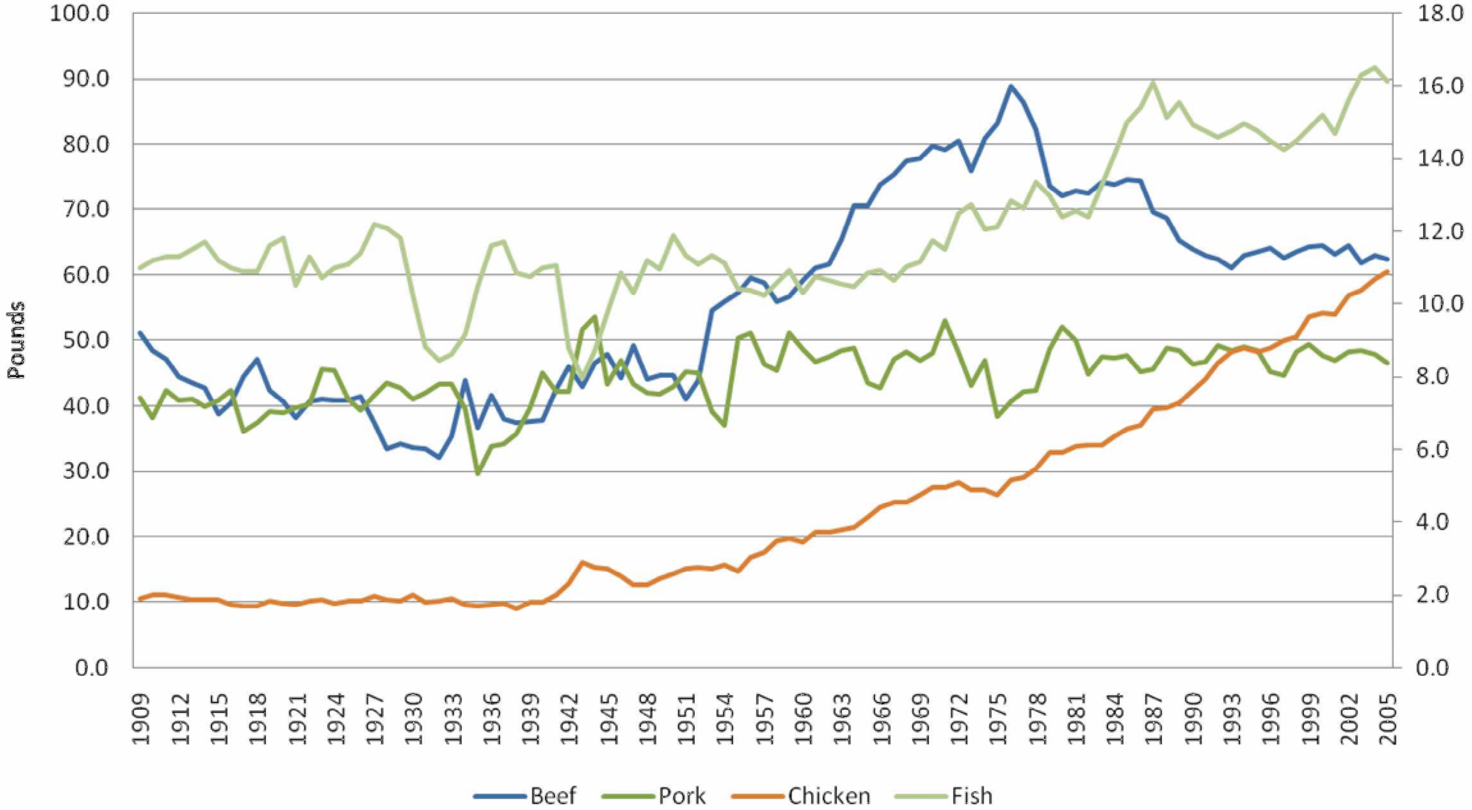

Table 1 - Summary Statistics of the Commodity Shares, Prices and Expenditure

Variable	N	Mean	Std Dev	Minimum	Maximum
sb	33	0.569365500	0.044427600	0.484091100	0.628992800
sp	33	0.290340700	0.009764400	0.273344100	0.312866100
sc	33	0.135625000	0.040555600	0.087679200	0.204331900
ss	33	0.004668900	0.000951868	0.002944600	0.007070300
Lpb	33	5.396715100	0.338091500	4.604586700	5.822259600
Lpp	33	5.142675300	0.356817200	4.245872800	5.596178400
Lpc	33	4.336240500	0.275454300	3.707455800	4.705166300
Lps	33	4.796686800	0.497810500	3.565447000	5.303281800
Lxp	33	10.866073600	0.167071500	10.640866200	11.178226000

Table 2 - Result of the estimated AIDs model

Parameter	Estimate	StdErr	tValue	Probt	DF
Beef Intercept	2.372943	0.7865	3.02	0.0055	27
Price of Beef	0.002871	0.0361	0.08	0.9371	27
Price of Chicken	-0.02893	0.0507	-0.57	0.5731	27
Price of Shrimp	0.010038	0.0143	0.7	0.4889	27
Disposable income	-0.16501	0.072	-2.29	0.03	27
Time slope coefficient	-0.00183	0.00145	-1.27	0.2166	27
Pork Intercept	-0.798746				
Price of Beef	0.036469				
Price of Chicken	-0.06067				
Price of Shrimp	-0.005286				
Disposable income	0.097275				
Time slope coefficient	-0.0016474				
Chicken Intercept	-0.62526	0.3502	-1.79	0.0854	27
Price of Beef	-0.0348	0.0161	-2.17	0.0392	27
Price of Chicken	0.088545	0.0226	3.92	0.0005	27
Price of Shrimp	-0.00835	0.00637	-1.31	0.2008	27
Disposable income	0.071705	0.0321	2.24	0.0338	27
Time slope coefficient	0.003476	0.00065	5.39	<.0001	27
Shrimp Intercept	0.051063	0.0303	1.69	0.1031	27
Price of Beef	-0.00454	0.00139	-3.27	0.0029	27
Price of Chicken	0.001055	0.00195	0.54	0.5931	27
Price of Shrimp	0.003598	0.00055	6.54	<.0001	27
Disposable income	-0.00397	0.00277	-1.43	0.1631	27
Time slope coefficient	1.46E-06	5.6E-05	0.03	0.9792	27

Table 3 - Nonlinear ITSUR Summary of Residual Errors

Equation	DF Model	DF Error	SSE	MSE	Root MSE	R^2	Ad. R^2
w_b	4	29	0.00777	0.000268	0.0164	0.8769	0.8642
w_p	4	29	0.00273	0.000094	0.00971	0.1047	0.0121
w_c	4	29	7.654E-6	2.639E-7	0.000514	0.7360	0.7087

Table 4 - Nonlinear ITSUR Parameter Estimates

Parameter	Estimate	Approx Std Err	t Value	Approx Pr > |t|
Gbb	0.002062	0.0332	0.06	0.9509
Gbp	0.011477	0.0205	0.56	0.5808
Gbc	-0.00428	0.00123	-3.47	0.0017
Gpp	-0.00704	0.0224	-0.31	0.7555
Gpc	0.000138	0.00140	0.10	0.9217
Gcc	0.003446	0.000489	7.05	<.0001
Ab	6.009096	0.3877	15.50	<.0001
Bb	-0.33805	0.0241	-14.03	<.0001
Ap	-0.10166	0.2538	-0.40	0.6916
Bp	0.024363	0.0158	1.55	0.1330
Ac	0.088654	0.0141	6.31	<.0001
Bc	-0.00521	0.000872	-5.97	<.0001

Table 5 - Nonlinear ITSUR Summary of Residual Errors

Equation	DF Model	DF Error	SSE	MSE	Root MSE	R^2	Ad. R^2
w_b	7	26	0.00569	0.000219	0.0148	0.9099	0.8892
w_p	7	26	0.00255	0.000098	0.00991	0.1638	-0.0291
w_c	7	26	7.261E-6	2.793E-7	0.000528	0.7496	0.6918

Table 6 - Nonlinear ITSUR Parameter Estimates

Parameter	Estimate	Approx Std Err	t Value	Approx Pr > |t|	Label
Gbb	-0.27025	0.3348	-0.81	0.4269	
Gbp	0.223682	0.2156	1.04	0.3092	
Gbc	-0.0093	0.00878	-1.06	0.2993	
Gbt	0.055859	0.1406	0.40	0.6944	
Gpp	-0.10323	0.1449	-0.71	0.4826	
Gpc	0.004397	0.00534	0.82	0.4175	
Gpt	-0.12485	0.0825	-1.51	0.1425	
Gcc	0.0033	0.000612	5.39	<.0001	
Gct	0.001598	0.00434	0.37	0.7156	
Gtt	0.067389	0.0686	0.98	0.3352	
Ab	2.814922	1.1577	2.43	0.0222	
Ap	-1.12897	0.7763	-1.45	0.1578	
Ac	0.045904	0.0488	0.94	0.3559	
At	-0.73186	0.5858	-1.25	0.2227	
Bb	-0.13638	0.0729	-1.87	0.0726	
abco1	0.001022	0.00386	0.26	0.7933	
absi1	-0.00346	0.00378	-0.91	0.3687	
ab_t	-0.00294	0.000935	-3.14	0.0041	
Bp	0.089438	0.0489	1.83	0.0788	
apco1	-0.00079	0.00259	-0.30	0.7632	
apsi1	0.002903	0.00253	1.15	0.2615	
ap_t	-0.00112	0.000640	-1.75	0.0918	
Bc	-0.00251	0.00308	-0.81	0.4234	
acco1	0.000118	0.000144	0.82	0.4219	
acsi1	-0.00006	0.000136	-0.42	0.6775	
ac_t	-0.00004	0.000046	-0.93	0.3616	
Restrict0	-161.955	67.6983	-2.39	0.0136	gbb + gbp + gbc + gbt = 0
Restrict1	-174.142	102.2	-1.70	0.0884	gbp + gpp + gpc + gpt = 0
Restrict2	-72.3853	694.6	-0.10	0.9194	gbc + gpc + gcc + gct = 0
Restrict3	5.52845	2.0534	2.69	0.0046	gbt + gpt + gct + gtt = 0
Restrict4	-6.83933	3.5481	-1.93	0.0519	ab + ap + ac + at = 1

Table 7 - Nonlinear ITSUR Estimates

Term	Estimate	Approx Std Err	t Value	Approx Pr > |t|	Label
elasticity beef	-1.06933	0.2446	-4.37	0.0002	(gbb - bb*(.5 - bb*9.0))/.5 - 1

Table 8 - Marshallian Elasticity Matrix

	BEEF	PORK	SHRIMP	CHICKEN
BEEF	-0.811434	0.1169067	-0.005525	-0.060421
PORK	-0.08251	-1.000664	0.0012535	-0.226122
SHRIMP	-0.504483	0.3232556	-0.268956	-0.012984
CHICKEN	-0.597613	-0.50049	-0.004656	-0.261826

Table 9 - Income Elasciticity

Income Elasticity	
BEEF	0.7604736
PORK	1.3080436
SHRIMP	0.463168
CHICKEN	1.3645854

Table 10 - Hicksian Elasticity Matrix

	BEEF	PORK	SHRIMP	CHICKEN
BEEF	-0.378447	0.3377032	-0.001974	0.0427182
PORK	0.6622445	-0.620886	0.0073606	-0.048719
SHRIMP	-0.240771	0.4577321	-0.266794	0.049833
CHICKEN	0.1793346	-0.104296	0.0017155	-0.076754