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Shrimp Ex-Vessel Prices Landed from the Gulf of Mexico

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Abstract *A 3SLS procedure is employed to analyze U.S. Gulf of Mexico shrimp ex-vessel prices by size class and import supplies using monthly time-series data for the period from 1981 to 1995. Results indicate that the U.S. Gulf of Mexico shrimp ex-vessel prices are inflexible. Own-price flexibilities range from –0.0663 to –0.1027. Primary substitutes for U.S. Gulf of Mexico shrimp are cross-size U.S. Gulf of Mexico shrimp and imported supplies from South America. Structural changes and seasonal variations are evident for U.S. Gulf of Mexico shrimp ex-vessel prices as well as import supplies.*

Key words Ex-vessel prices, flexibilities, Gulf of Mexico shrimp, import supplies, structural changes.

Introduction

The shrimp (*Panaeus*) fishery has been the most important commercial fishery of the United States. In 1995, 300 million pounds of shrimp, with a dockside value of $600 million dollars, were landed in U.S. waters. Approximately 70% of the total 1995 U.S. shrimp landings was caught in the Gulf of Mexico, making the Gulf of Mexico shrimp fishery the most important component of the U.S. shrimp fishery (U.S. Department of Commerce 1996).

Despite its significance, the shrimp fishery has faced a problem of declining landings. Since 1980, landings have declined steadily from 340 million pounds, to 300 million pounds in 1995. However, shrimp consumption in the United States has increased substantially in volume and value during the last decade. On average, annual per capita shrimp consumption rose from 2 to 2.5 pounds between 1985 and 1995, an increase of 25% (U.S. Department of Commerce 1995). Because of the decline in domestic landings along with the growth in shrimp consumption, U.S. shrimp supplies have been augmented by imports during the 1980s and the 1990s. As figure 1 illustrates, the amount of imported shrimp has increased dramatically from 260 million pounds (headless shell-on equivalent weight basis) in 1981 to 720 million pounds in 1995, an increase of 175% (U.S. Department of Commerce 1982

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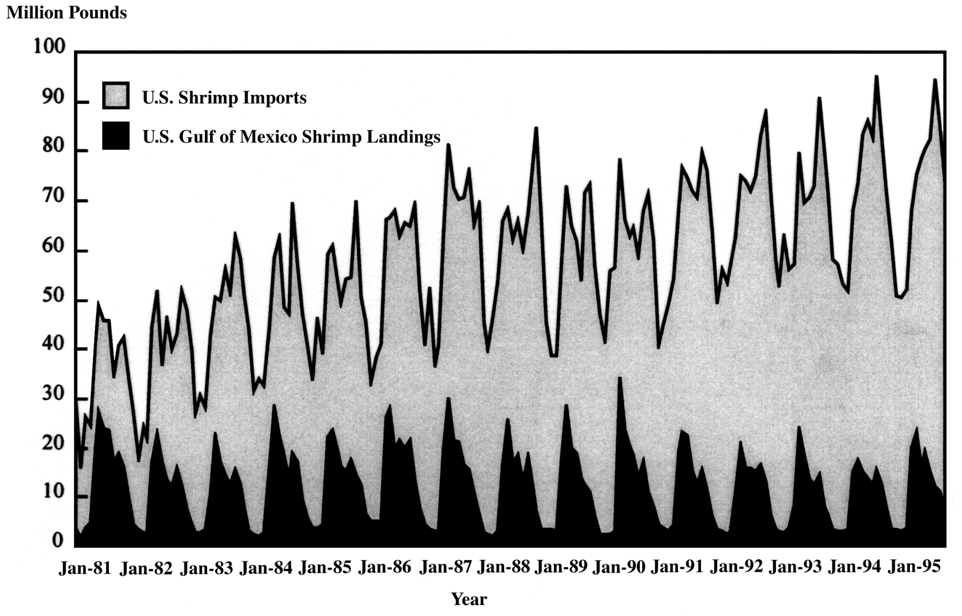

Figure 1. U.S. Gulf of Mexico Shrimp Landings and U.S. Shrimp Imports, 1981–95

and 1996). Additionally, most of the increase in imported supplies has come from farm-raised shrimp (aquaculture) since world wild supplies of shrimp are fully utilized (Roberts, Keithly, and Adams 1990; and O'Connell 1988). Within less than two decades, aquacultural shrimp production has grown more than 1000%, from 80 million pounds (headless shell-on equivalent weight basis) in 1980, to 900 million pounds in 1995 (Vondruska 1996).

Literature Review

In the literature, several studies were undertaken to examine the U.S. shrimp fishery; however, most of the studies were conducted before the 1980s, prior to a period when imports increased their role as a major source of supply in the U.S. shrimp market. Moreover, some of these previous studies did not consider in their analyses the effect of cross-size Gulf of Mexico landings on ex-vessel prices. Further, some employed annual data rather than monthly data in their analyses; therefore, impacts from seasonal variations on ex-vessel prices may be overlooked. Specific examples of closely related research are given below.

Doll (1972) used annual data from 1958 to 1968 to estimate three levels of the U.S. shrimp market (retail, wholesale, and ex-vessel) using a three-stage least squares (3SLS) procedure; however, the effect of cross-size Gulf of Mexico landings (cross-size) was not considered. Chui (1980) and Blomo *et al.* (1982) used monthly data from 1963 to 1977 to estimate U.S. shrimp demand and included cross-size substitution effects in their models. Shrimp were disaggregated into three sizes: less than 30, between 30–50, and greater than 50 (headless) counts per pound. While Chui (1980) estimated each size category independently to estimate ex-vessel demand for Gulf of Mexico shrimp, Blomo *et al.* (1982) applied a system of equations to estimate ex-vessel demand functions for shrimp from West Florida.

Hopkins (1983) used annual data from 1955 to 1980 to study the impact of import regulations (*i.e.*, different levels of tariff or quota) on the shrimp fishery. Thompson and Roberts (1983) employed monthly data from 1974 to 1980 to study the U.S. shrimp market focusing on the relationship between wholesale and the ex-vessel levels. Later Lea and Shonkwiler (1988) used data from the Thompson and Roberts study to examine misspecification issues related to their shrimp model. O'Connell (1988) examined the demand for U.S. warmwater and Ecuadorian shrimp for the specific sizes from 21 to 41 counts per pound. Monthly data from December 1984 to April 1987 were used in this analysis. O'Connell found that ex-vessel prices were impacted by cold storage holdings, but not by own-size landings and cross-size landings.

Keithly, Roberts, and Ward (1993) examined U.S. and Japanese shrimp import markets simultaneously using annual observations for the period from 1965–89. A 3SLS procedure was used to estimate the parameters. As expected, the results showed that imports lowered domestic prices. Adams, Prochaska, and Spreen (1987) used quarterly and monthly data from 1972 to 1981 to explain price movement of shrimp at three different levels (retail, wholesale, and ex-vessel). Gulf and South Atlantic shrimp sizes 21–25 and 31–40 counts per pound were used for the ex-vessel level analysis. Later Adams (1993) examined the South Atlantic rock shrimp market by using data from 1981 to 1991. In this study, a set of dummy variables was used to represent size classes between 21 and 55 counts per pound to capture a cross-size landings effect. The works by Adams, Prochaska, and Spreen (1987) and Adams (1993) suggested that income was an insignificant factor in affecting shrimp prices at the ex-vessel level.

This study is designed to overcome several shortcomings from these previous studies. A principal objective of this study is to analyze the factors affecting shrimp ex-vessel prices landed from the U.S. Gulf of Mexico. In this analysis, we take into account landings of cross-size Gulf of Mexico shrimp and imported shrimp using monthly time-series data for the period from 1981–95. The reason for focusing the study on the U.S. Gulf of Mexico shrimp fishery is that this fishery is predominant among all U.S. shrimp fisheries.

This study is differentiated from previous studies in several ways. First, none of the previous studies to date have analyzed the Gulf of Mexico shrimp fishery using both monthly time-series data from the period 1981–95 and three sizes of shrimp: less than 30 (large-size); between 30 to 67 (medium-size); and greater than 67 (small-size) counts per pound (headless, shell-on equivalent weight basis). The use of data from 1981 through 1995 provides a more up-to-date picture of the U.S. Gulf of Mexico shrimp fishery. By categorizing shrimp into three size classes, the cross-size class effects on ex-vessel prices can be identified. Since monthly data, rather than quarterly or yearly data are used, seasonal effects can also be captured.

Second, in this study, imported shrimp has been disaggregated into three different groups according to their countries of origin. In previous studies, disaggregation of U.S. import supplies was not attempted. The three regions considered are Central America, South America, and Asia. Imports from these regions account for almost 97% of total U.S. imports (USDC 1980–95). On average, the import shares for Central America, South America, and Asia are 17%, 26%, and 57% respectively. Imported shrimp from the Central American region has been evenly distributed among size classes over the last six years (1990–95). The average size distribution of shrimp from Central America consisted of 32% large size shrimp, 31% medium size shrimp, and 37% small size shrimp (National Marine Fisheries Service). Of the total South American shrimp imported, 46% are of medium-size, 15% are of large-size, and 39% are of small-size. Shrimp from Asia are imported in a wide range of size classes, but the majority are of the small-size class, accounting for 53% of landings.

Model Development and Specification

In a natural resource-based industry like the shrimp fishery, supplies (landings) are primarily determined by biological and environmental conditions (Adams 1993; Greenberg, Hermann, and McCracken 1995; and Chui 1980); therefore, ex-vessel prices are adjusted in accordance with landings. Hence, a price-dependent specification is used in our analysis of the U.S. Gulf of Mexico shrimp fishery. This specification conforms to previous studies (Doll 1972; Chui 1980; Blomo et *al*. 1982; Thompson and Roberts 1983; Hopkins 1983; Adams, Prochaska, and Spreen 1987; O'Connell 1988; Keithly, Roberts, and Ward 1993; and Adams 1993). In addition, the price-dependent specification is more useful and appropriate for assessing the impact of management policies which likely involves quantity (harvest) restrictions. This price-dependent specification deals with three size classes of shrimp: (*i*) less than 30 (large); (*ii*) between 30 to 67 (medium); and (*iii*) greater than 67 (small) headless shell-on tail counts per pound.

According to the economic theory, ex-vessel shrimp prices for each size are expected to be influenced by own-landings, cross-size landings (U.S. Gulf of Mexico shrimp), landings from other domestic sources (Atlantic shrimp), imported landings, and cold-storage holdings. Domestic landings and imported landings, as well as cold storage holdings, are expected to have a negative effect on U.S. Gulf of Mexico ex-vessel prices.

Chui (1980) and O'Connell (1988) showed that landings from adjacent sizes of Gulf of Mexico shrimp affected the ex-vessel prices of a particular size. All cross-size Gulf of Mexico shrimp landings are initially included in the model to test this hypothesis. Atlantic shrimp are hypothesized to be substitutes for Gulf of Mexico shrimp; therefore, a negative relationship with the Gulf of Mexico ex-vessel prices is anticipated. Due to the lack of data available by size class, Atlantic shrimp landings were not disaggregated by size class.

Cold storage holdings are lagged by one period to reflect beginning monthly stocks. In addition, cold storage holdings are divided into a headless shell-on product form and a processed product form. The headless shell-on cold storage product form is expected to have a negative impact on U.S. Gulf of Mexico shrimp ex-vessel prices of large and medium size classes. The processed product form is expected to have a negative effect on the U.S. Gulf of Mexico ex-vessel price of the small size class.

According to the studies by Doll (1972), Keithly, Roberts, and Ward (1993), and Upton, Hoar, and Upton (1992), imported shrimp and domestic shrimp are close substitutes. Therefore, imported shrimp landings are hypothesized to have a negative effect on U.S. Gulf of Mexico ex-vessel prices. It is unlikely that contemporaneous imported landings will influence ex-vessel prices due to the manner in which imported shrimp flows into the U.S. market. Before reaching the consumer, shrimp imports change hands several times from importers to processors to primary wholesalers. Imported shrimp are then passed on to secondary wholesalers, retailers, and finally end-user consumers (O'Connell 1988). Additionally, since most of the imported shrimp is from aquaculture, contracts of shrimp sales, and thus price, may be established ahead of time before shrimp are imported to the U.S. market (Keithly 1996). Yet, these frozen imported shrimp cannot be held for long periods without deteriorating in quality resulting in price reductions. Therefore, it is reasonable to consider imported landings lagged one or two periods to determine the impact of imports on ex-vessel prices.

It may be inappropriate to assume that imported shrimp landings are exogenous in our U.S. Gulf of Mexico shrimp ex-vessel price model. To account for their endogeneity, imported supplies are specified as a function of own-U.S. imported price, U.S. income level, structural shifts, and seasonal variation. The predicted values of these relationships are used as instrument variables in the U.S. Gulf of Mexico shrimp ex-vessel price equations.

The own-imported price is hypothesized to have a positive impact on import supply. In contrast to the study by Adams, Prochaska, and Spreen (1987) which included an income variable in the ex-vessel price equation to capture the relationship between income and ex-vessel price, our study includes an income variable in the U.S. import supply equations. United States per capita real disposable income is expected to positively affect import supplies. Thus, through import supplies we may track the impact of changes in income on shrimp ex-vessel prices from the Gulf of Mexico. Increases in income are expected to lead to increases in import supplies. However, an increase in import supplies is hypothesized to lead to a reduction in ex-vessel prices.

Increased quantities of imports since 1980 are a primary reason for changes in the U.S. shrimp supply (Roberts, Keithly, and Adams 1990; Keithly, Roberts, Ward 1993; and O'Connell 1988). The growth in imports also corresponds, in part, with the development of shrimp-farming (aquaculture) (Upton, Hoar, and Upton 1992). Owing primarily to aquaculture, structural changes in U.S. Gulf of Mexico shrimp ex-vessel prices, as well as in the U.S. import supplies, are investigated. To capture the magnitude of these changes, dummy variables corresponding to the period in which the structural shifts occurred are included in the U.S. import supply equations and in the U.S. Gulf of Mexico shrimp ex-vessel price equations. We consider time periods from 1980 to 1989 to determine the presence of structural shifts in import supplies and U.S. Gulf of Mexico shrimp ex-vessel prices. The choice of the particular period corresponding to structural change rests on statistical significance of the coefficients associated with the dummy variables and the Akaike Information Criterion (AIC).

Plots of average monthly landings of the Gulf of Mexico shrimp, by size, from 1981–95 (figures 2 and 3) suggest that seasonal variation in landings and ex-vessel prices is evident. Generally, the smaller shrimp are caught earlier in the season, while the larger shrimp are caught later in the season after they have had a chance to migrate offshore. The landings for large shrimp are high from August to December

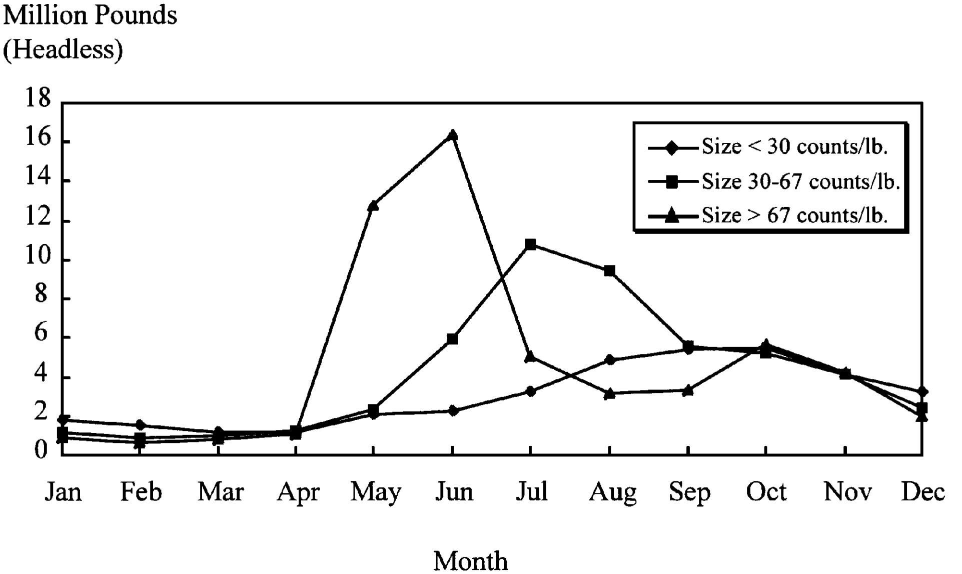

Figure 2. Average Landings of the U.S. Gulf of Mexico Shrimp, 1981–95

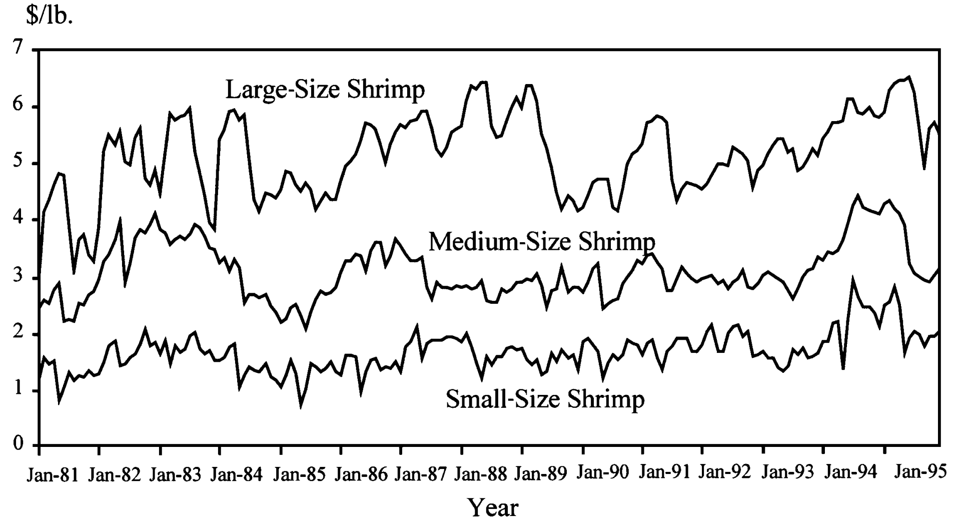

Figure 3. U.S. Gulf of Mexico Ex-Vessel Prices by Size Classes, 1981–95

with the peak month being October. Medium shrimp landings are concentrated from June to December and peak in July, three months earlier than large shrimp. The season for small shrimp runs from May to December, with June giving the highest yield.

To estimate seasonal shifts in U.S. Gulf of Mexico shrimp ex-vessel prices, as well as in U.S. import supplies, a set of dummy variables is added corresponding to months where January is arbitrarily used as a base month. In addition, these eleven monthly dummy variables are interacted with own-Gulf of Mexico shrimp landings in order to capture the potential variation in own-price flexibilities by month.

Given this backdrop, the U.S. Gulf of Mexico shrimp ex-vessel price model categorized by size class is specified as follows:

$$P_i = f_i(Q_i, Q_{j,j \neq i}, AQ, BIQ, IQ_k, SI, SS, S) \quad i = 1, 2, 3 \tag{1}$$

$$IQ_k = g_k(IP_k, Y, SI, SS, S) \quad k = 1, 2, 3 \tag{2}$$

where i, j = large size (less than 30 counts per pound), medium size (between 30–67 counts per pound), and small size (greater than 67 counts per pound), and k = Central America, South America, and Asia. All equations are estimated in the linear functional form. Variable definitions are presented in table 1.

Data

Monthly time-series data for the period from January 1981 to December 1995 are used. The data regarding shrimp landings in the Gulf of Mexico and in the Atlantic, cold storage quantities, import quantities, and nominal ex-vessel shrimp prices were provided by the National Marine Fisheries Service (NMFS).

For comparability, all quantities (landings) used in the analysis have been converted to a headless shell-on equivalent weight basis. A ratio of 0.629 is used to convert landings of the Gulf of Mexico shrimp and the Atlantic shrimp from a head-on

Table 1
Variable Definitions

Variable Names	Variable Definitions	Units
$P_{i,t}$	Deflated (1987 dollars) U.S. Gulf of Mexico shrimp ex-vessel prices by three size categories (large, medium, and small) in month *t*	cents per pound
$Q_{i,t}$	U.S. Gulf of Mexico shrimp landings by three size categories (large, medium, and small) in month *t*	lbs.[a]
AQ_t	Aggregate U.S. Atlantic shrimp landings in month *t*	mill. lbs.
$BIQ_{1,t}$	Beginning of the month U.S. Gulf of Mexico cold storage holdings of shrimp, a headless shell-on product in month *t*	mill. lbs.
$BIQ_{2,t}$	Beginning of the month U.S. Gulf of Mexico cold storage holdings of shrimp, a processed form in month *t*	mill. lbs.
$IQ_{k,t-1}$	U.S. import supply by country of origins (Central America, South America, and Asia) in month $t - 1$	mill. lbs.
$IP_{k,t-1}$	U.S. import price by country of origins (Central America, South America, and Asia) in month $t - 1$	mill. lbs.
Y_t	U.S. per capita real disposable income in month *t*	dollars
S84, S85, S88, and S89	Structural change (Trend) dummy variables equal to one if a period of change occurred since 1984, 1985, 1988, and 1989, respectively; otherwise, zero.	
SI and SS	Seasonal variation dummy variables (through intercept and slope shifters, respectively)	January is a base month

Note: [a] all quantities (landings) have been converted to a headless shell-on equivalent weight basis.

to a headless shell-on equivalent weight basis. United States import quantities and the cold storage holdings include different product forms, such as headless shell-on, peeled, breaded, canned, and other forms; therefore, ratios of 1, 1.28, 0.63, 2.52, and 2.4, respectively, are used to convert these quantities to a headless shell-on equivalent weight basis.

United States nominal monthly disposable income data were obtained from *Survey of Current Business*. United States per capita real disposable income was derived by dividing the U.S. nominal disposable income by the resident population (Bureau of Census) and by dividing this result by the U.S. Implicit-Price-Deflator, base 1987 = 100. All nominal ex-vessel prices were deflated by the U.S. Implicit-Price-Deflator, base 1987 = 100. Summary statistics of selected variables in this study are provided in table 2.

The average nominal ex-vessel price for the U.S. Gulf of Mexico shrimp by size class ranged from \$1.66/lb. (small-size) to \$5.15/lb. (large-size). Large U.S. Gulf of Mexico shrimp landings account for 25% of total landings. Medium and small U.S. Gulf of Mexico shrimp landings make up 35% and 40% of total landings, respectively.

Table 2
Selective Descriptive Statistics for the U.S. Gulf of Mexico Shrimp Model

Variable Names	Mean	Standard Deviation	Minimum	Maximum
Actual ex-vessel price ($/lb.)				
$P_{< 30 \text{ counts per pound}}$	5.15	0.71	2.97	6.50
$P_{30\text{–}67 \text{ counts per pound}}$	3.09	0.49	2.07	4.41
$P_{> 67 \text{ counts per pound}}$	1.66	0.35	0.72	2.93
Quantity (mill. lbs.)[a]				
$Q_{< 30 \text{ counts per pound}}$	3.03	1.82	0.62	8.93
$Q_{30\text{–}67 \text{ counts per pound}}$	4.18	3.46	0.59	15.85
$Q_{> 67 \text{ counts per pound}}$	4.76	5.32	0.15	30.37
AQ	1.40	1.07	0.05	5.03
IQ_C^*	9.31	4.00	3.01	20.06
IQ_S^*	10.44	3.29	2.83	17.20
IQ_A^*	17.55	9.67	1.83	41.55
$BIQ_{\text{headless shell-on}}$	49.02	9.05	30.55	78.95
$BIQ_{\text{processed form}}$	3.48	0.89	1.43	5.55

Notes: * C refers to Central American region, S refers to South American region, and A refers to Asian region.
[a] all quantities (landings) have been converted to a headless shell-on equivalent weight basis.

Methodology

A system of six linear equations using a three-stage least squares (3SLS) procedure is employed to estimate the U.S. Gulf of Mexico shrimp ex-vessel price model. The 3SLS procedure was used for two reasons. The first reason is the contemporaneous correlation that exists among the disturbance terms (*i.e.*, environmental conditions) of the U.S. Gulf of Mexico shrimp ex-vessel price equations. According to Kmenta (1986), Judge *et al.* (1988), and Greene (1993), when contemporaneous correlation exists and the exogenous variables from each equation are different, the estimated coefficients obtained using the system equations procedure are more efficient than those derived from ordinary least squares (OLS). The second reason is that U.S. imported shrimp quantities are endogenous to the U.S. Gulf of Mexico shrimp ex-vessel price model. Predicted values from the import supply equations are used as instrument variables in the U.S. Gulf of Mexico shrimp ex-vessel price equations. Durbin-Watson (DW) tests are used to check for a serial correlation. The AUTO and DRHO (a different value of RHO is given to each equation) options within the SHAZAM computer package is used to examine and to correct for serial correlation using Pagan's procedure.

Empirical Results/Structural Analysis

The structural model [equations (1) and (2)] previously described is initially estimated using the 3SLS estimation procedure. Results from the structural model show that neither Atlantic shrimp landings nor cold storage holding quantities have a statistically significant impact on the U.S. Gulf of Mexico shrimp ex-vessel prices. In addition, cross-size Gulf of Mexico landings exhibit different impacts on Gulf of Mexico shrimp ex-vessel price by size class. The ex-vessel price of large-size Gulf of Mexico shrimp is influenced by landings of medium-size shrimp, while the ex-vessel price of medium-size shrimp is influenced by small-size landings. This next-smaller-cross-size-class substitution pattern is consistent with the findings of previous studies (Chui 1980 and O'Connell 1988). Small-size class Gulf of Mexico shrimp are impacted by large-size Gulf of Mexico landings, not medium-size landings.

The results from the structural model show that U.S. Gulf of Mexico shrimp ex-vessel prices are influenced by imported landings. The impacts of imports on Gulf of Mexico ex-vessel prices differ according to size class. Supplies from South America have a statistically significant effect on the Gulf of Mexico ex-vessel prices of all size classes, whereas import supplies from Central America and Asia significantly affect small and medium-sized Gulf of Mexico shrimp ex-vessel prices, respectively.

For the U.S. import supply equations, all the coefficients have the expected sign except for the coefficient associated with own-imported price in the South American supply equation; but, this unexpected sign of U.S. imported price is insignificant. This result implies that U.S. import supplies are, in part, influenced by U.S. imported prices, U.S. per capita real disposable income, structural changes, and seasonal variation.

We re-estimated the U.S. Gulf of Mexico shrimp ex-vessel price model using a 3SLS procedure after all of the insignificant variables discussed above were dropped from the structural model. There is no perceptible change in the goodness-of-fit statistic (R^2) and in the DW test statistic values. Therefore, we report only the results of the re-estimated model.

As exhibited in table 3, the estimated equations have good explanatory power. The range of the R^2 statistics varies from 0.77 to 0.94. Estimated coefficients have the expected signs. Price flexibilities of the U.S. Gulf of Mexico shrimp and elasticities of the U.S. import supplies are calculated at the sample means and are presented in table 4.

Results from table 4 show that all of the own-price flexibilities are negative, consistent with *a priori* expectations. These own-price flexibilities are weighted flexibilities taking into account seasonal variations. The own-price flexibilities range from –0.0663 (medium-size) to –0.1027 (large-size). According to previous studies, own-price flexibilities ranged from –0.038 to –0.79 (Doll 1972; Chui 1980; Adams, Prochaska, and Spreen 1987; O'Connell 1988; and Keithly, Roberts, and Ward 1993). The own-price flexibilities from the Chui study (1980) are perhaps the most comparable to this study in terms of time period and size distribution. The comparison between Chui's results and this study indicates that Gulf of Mexico shrimp ex-vessel price flexibilities have gradually increased over time. Own-price flexibilities for large-, medium-, and small-size shrimp have increased from –0.060, –0.038, and –0.065 (Chui) to –0.103, –0.066, and –0.073, respectively. Even if the own-price flexibilities have increased in recent years, the small magnitude of these own-price flexibilities indicate that the U.S. Gulf of Mexico shrimp fishery is highly price inflexible. Hence, even though the U.S. Gulf of Mexico shrimp ex-vessel prices decrease as a result of increases in harvest, shrimp fishermen's revenues still increase.

Moreover, since an inversion of flexibility represents the lower bound of elasticity, large-size Gulf of Mexico shrimp is less elastic than medium- and small-size Gulf of Mexico shrimp. These findings are reasonable given that medium- and small-size Gulf of Mexico shrimp have more substitutes, in particular from import supplies, than large-sized Gulf of Mexico shrimp. Only imported shrimp from South America is substituted for the large-size Gulf of Mexico shrimp, whereas South American and Asian shrimp are substituted for medium-size Gulf of Mexico shrimp; Central American and Asian shrimp are substituted for small-size Gulf of Mexico shrimp.

The results in table 4 show that cross-size price flexibilities are negative as ex-

Table 3
Econometric Results for the U.S. Gulf of Mexico Shrimp Model, 1981–95

Variables	Units	Ex-vessel Price of Large Shrimp Eq. (1)	Ex-vessel Price of Medium Shrimp Eq. (2)	Ex-vessel Price of Small Shrimp Eq. (3)	Import Supply from Central America Eq. (4)	Import Supply from South America Eq. (5)	Import Supply from Asia Eq. (6)
Intercept		6.3319*	4.0729*	2.5458*	–33.78*	–14.937*	–50.404*
		(18.55)[a]	(15.36)	(11.32)	(4.22)	(2.30)	(3.53)
$Q_{<30\text{ ct./lb.}}$	mill. lbs.	–0.1682*		–0.0362*			
		(5.53)		(1.98)			
$Q_{31\text{-}67\text{ ct./lb.}}$	mill. lbs.	–0.0417*	–0.0473*				
		(2.19)	(2.36)				
$Q_{>67\text{ ct./lb.}}$	mill. lbs.		–0.0098*	–0.0241*			
			(2.41)	(3.48)			
$IQ^{b}_{C,t-1}$	mill. lbs.			–0.0230*			
				(2.11)			
$IQ^{b}_{S,t-1}$	mill. lbs.	–0.0291*	–0.0224*	–0.0282*			
		(1.30)	(1.73)	(2.49)			
$IQ^{b}_{A,t-1}$	mill. lbs.		–0.0063*				
			(1.61)				
IP^{b}_{C}	cents/lb.				2.5077*		
					(3.91)		
IP^{b}_{S}	cents/lb.					–0.1004	
						(0.21)	
IP^{b}_{A}	cents/lb.						3.493*
							(2.28)
Y	dollars				0.2775*	0.1667*	0.4218*
					(5.68)	(3.71)	(3.68)
Structural change		–0.7503*[d]	–0.6073*[e]		–4.5382*[f]	1.6382*[g]	6.0466*[d]
		(2.74)	(3.55)		(4.68)	(1.55)	(2.13)
Seasonal intercept shifters[c]		0.2374	0.4905	0.0206*	0.0000*	0.0000*	0.0000*
Seasonal slope shifters[c]		0.0169*	0.0105*	0.0718*			
R-squared		0.8987	0.9364	0.7662	0.7752	0.8199	0.8851
Rho		0.8432*	0.8882*	0.8007*	0.3856*	0.6018*	0.7129*
DW		1.72	1.83	2.15	2.25	2.38	1.97

Notes: * indicates significance at the 0.10 level.
[a] Absolute t-ratio values in parentheses.
[b] C refers to Central American region, S refers to South American region, and A refers to Asian region.
[c] p-values.
[d] Dummy variables equal to 1, if 1989 and later; 0 otherwise.
[e] Dummy variables equal to 1, if 1984 and later; 0 otherwise.
[f] Dummy variables equal to 1, if 1988 and later; 0 otherwise.
[g] Dummy variables equal to 1, if 1985 and later; 0 otherwise.

pected. Medium-size Gulf of Mexico shrimp substitutes for large-size shrimp, small-size Gulf of Mexico shrimp substitutes for medium-size shrimp, and large-size Gulf of Mexico shrimp substitutes for small-size shrimp. This substitution pattern indicates that for large- and medium-size Gulf of Mexico shrimp, smaller-size Gulf of Mexico shrimp tend to substitute more easily than larger-size Gulf of Mexico shrimp. The fact that the own-price flexibilities are greater than their cross-price flexibilities is consistent with the previous studies (Chui 1980) and implies that their ex-vessel prices are more responsive to their own-size landings than to their cross-

Table 4
Estimated Ex-Vessel Price Flexibilities and Import Supply Elasticities for the U.S. Gulf of Mexico Shrimp Model

	Ex-Vessel Prices		
	Shrimp Size Less Than 30 Counts/lb.	Shrimp Size Between 30–67 Counts/lb.	Shrimp Size Greater Than 67 Counts/lb.
$Q_{<30\text{ counts/lb.}}$ Flexibility	–0.1027* (5.53)[a]		–0.0693* (1.98)
$Q_{30\text{-}67\text{ counts/lb.}}$ Flexibility	–0.0352* (2.19)	–0.0663* (2.36)	
$Q_{>67\text{ counts/lb.}}$ Flexibility		–0.0157* (2.41)	–0.0726* (3.48)
$IQ^{b}_{C,t-1}$ Flexibility			–0.1343* (2.11)
$IQ^{b}_{S,t-1}$ Flexibility	–0.0609* (1.30)	–0.0781* (1.73)	–0.1858* (2.49)
$IQ^{b}_{A,t-1}$ Flexibility		–0.0369* (1.61)	
	Import Supplies		
	Central America	South America	Asia
Own-elasticity of import supply	1.0499* (3.91)	–0.0335 (0.21)	0.5384* (2.28)
Income elasticity of import supply	3.9563* (5.68)	2.1200* (3.71)	3.1917* (3.68)

Notes: * indicates significance at the 0.10 level.
[a] Absolute t-ratio values in parentheses.
[b] C refers to Central American region, S refers to South American region, and A refers to Asian region.

size landings. For instance, a 10% increase in large Gulf of Mexico shrimp landings results in a 1% decrease in its ex-vessel price, whereas a 10% increase in the cross-size Gulf of Mexico landings (medium-size landings) leads to a drop of 0.4% in large-size ex-vessel price.

Negative and statistically significant import flexibilities, shown in table 4, conform to expectations. South American imports affect the U.S. Gulf of Mexico shrimp ex-vessel prices of all size classes. This finding implies that imported shrimp from South America is more closely substituted for Gulf of Mexico shrimp. Additionally, import flexibilities shown in table 4 indicate that small-size Gulf of Mexico shrimp ex-vessel price is the most responsive to import supplies. The import flexibilities for the small-size class are –0.1343 (from Central America) and –0.1858 (from South America). For imports from South America, the import flexibility for small-size Gulf of Mexico shrimp (–0.1858) is twice as large as the import flexibilities for medium-size (–0.0781) or large-size (–0.0609) Gulf of Mexico shrimp ex-vessel prices. For imports from Asia, the import flexibility for the medium-size class is –0.0369.

Structural changes in U.S. Gulf of Mexico shrimp ex-vessel prices of large and medium shrimp sizes occurred in 1989 and 1984, respectively. Structural changes in U.S. import supplies also occurred in 1988, 1985, and 1989, for large-, medium-, and small-size shrimp, respectively. These structural changes led to a leftward shift in the U.S. Gulf of Mexico shrimp ex-vessel demand; *ceteris paribus*, U.S. Gulf of

Mexico shrimp ex-vessel prices are lower by $0.75 per pound for the large-size and $0.60 per pound for the medium-size. No evidence of a structural change for small-size Gulf of Mexico shrimp exists.

Since the mid 1960s, shrimp imports have increased significantly; however, most of the increase occurred during the 1980s, particularly after 1984. For example, annual 1985–95 imports averaged 600 million pounds compared to 350 million pounds imported annually from 1981–84, an increase of 70% (U.S. Department of Commerce, 1981–95). This import growth corresponds with the development of shrimp farming (aquaculture) (Upton, Hoar, and Upton 1992).

A structural shift during 1989 occurred as a consequence of an increase of more than 200% of the exported shrimp (mainly black tiger) from China and Thailand, two of the world's leading producers of farm-raised shrimp, into the U.S. market (U.S. Department of Commerce). The amount of the U.S. imported shrimp from China jumped from 42 million pounds exported in 1987, to more than 100 million pounds during 1988–90, and then decreased to 32 million pounds in 1995. While the U.S. supply from China has been decreasing since 1991, the U.S. supply from Thailand has increased from less than 50 million pounds prior to 1991, to more than 100 million pounds after 1991, and reached 172 million pounds in 1995 (U.S. Department of Commerce). A structural shift in the U.S. Gulf of Mexico shrimp ex-vessel price demand for medium-size Gulf of Mexico shrimp during 1984 may be a result of an increase in the supply from South America, with the majority of the shrimp being of the medium size class. In the early 1980s, imported shrimp from South America was less than 100 million pounds, then in the later 1980s until the present, imported shrimp from South America has increased to 165 million pounds in 1995.

As exhibited in table 4, own-price elasticities of import supply are positive and statistically significant in sign as expected, except for South America; however, this unexpected negative own-price effect is insignificant. One possible explanation of this insignificant result is that the U.S. market is the only main market for the South American shrimp, in contrast to imported shrimp from Central America or Asia, which are marketed in the United States, Japan, Europe, and other countries. As a result, the U.S. import price may not be a significant factor determining changes in the import supply of South American shrimp. The fact that the own-price elasticity of Central American imported shrimp is twice as great as the own-price elasticity of Asian imported shrimp suggests that imported quantities from Central America are more responsive to price changes than imported quantities from Asia.

Income changes have a positive effect on import supplies. In fact, import supplies are very sensitive to changes in U.S. per capita disposable income. The income elasticities of import supplies range from 2.12 (South America) to 3.95 (Central America). As import supplies increase, Gulf of Mexico ex-vessel prices decrease; consequently, the relationship between income and ex-vessel price variables is negative. However, this negative relationship does not imply that shrimp are inferior goods. In fact, as incomes rise, more shrimp is imported. The negative relationship between income and ex-vessel price also was found in the study by Adams, Prochaska, and Spreen (1987). In this study, an income variable was included directly in the ex-vessel price equation as a demand shifter rather than being included in import supply relationships.

Results from table 3 confirm that structural changes in U.S. import supplies exist. Statistical evidence suggests that a structural change in import supplies from South America was evident beginning in 1984. A structural change in import supply from Asia occurred during 1989. Since 1984, import supply from Asia has gradually increased which was at a time when aquacultural shrimp farming began, then in 1989 imported supplies from Asia dramatically increased as aquacultural shrimp farming became dominant. In contrast to changes in supplies from South America and Asia, structural change in import supplies from Central America led to declines in this region beginning in 1988.

As exhibited in table 3, seasonality influences ex-vessel prices as well as the U.S. import supplies. Import supplies increase during the off-domestic season and decrease during the domestic season, as expected. Additionally, the results show that even though seasonality influences only the level of small-size Gulf of Mexico shrimp ex-vessel price, seasonality affects own-price flexibilities of all sizes of Gulf of Mexico shrimp. Ex-vessel prices receive a premium at the beginning of the season, then they are discounted during the latter part of the season. The Gulf of Mexico ex-vessel prices of large- and medium-size classes do not exhibit any seasonality because of an increase in the importance of the role of aquacultural shrimp imports in the U.S. shrimp supplies. These supplies from aquacultural shrimp exhibit less seasonality than wild-caught supplies.

Concluding Remarks

A system of six equations using a 3SLS procedure was employed to analyze U.S. Gulf of Mexico shrimp ex-vessel prices, divided into three cross-size classes, using monthly time-series data from 1981 to 1995. Findings from this study indicate that the variation of the U.S. Gulf of Mexico shrimp ex-vessel prices is, in general, partly influenced by own-size landings, cross-size landings, imported shrimp quantities, the U.S. per capita disposable income, structural shifts, and seasonality. Atlantic shrimp landings and cold storage holdings have an insignificant impact on Gulf of Mexico shrimp ex-vessel prices. Results indicate that the U.S. Gulf of Mexico shrimp fishery is highly price inflexible. The Gulf of Mexico shrimp ex-vessel prices are more responsive to their own-size landings than to cross-size landings. Substitutions in the U.S. Gulf of Mexico shrimp are predominantly from Gulf of Mexico shrimp cross-size landings and U.S. shrimp imports. Imports from South America have the most significant influence on Gulf of Mexico shrimp ex-vessel prices. Small-size Gulf of Mexico shrimp ex-vessel prices are the most responsive to U.S. import supplies. Seasonal variations and structural shifts in the Gulf of Mexico shrimp ex-vessel prices and import supplies are evident.

With knowledge of the factors that influence the U.S. Gulf of Mexico shrimp fishery, shrimp fishermen can choose an appropriate harvest pattern (*i.e.*, preferred cross-size shrimp landings or time to harvest) corresponding to changes in market conditions, to maximize their profits. Likewise, a policymaker can choose a management policy that introduces some market distortions (*i.e.*, restrictions on domestic harvests or import supplies) to maximize gains or to minimize losses for all parties involved (*i.e.*, consumers, shrimp fishermen, or importers).

A possible study for future research may involve the analysis of the effects of alternative management policies involving harvest, especially, Turtle Excluder Devices (TED) and Bycatch Reduction Devices (BRD). By incorporating the price flexibilities from this study into a general bioeconomic fishery simulation model (GBFSM) (Grant and Griffin 1979), the GBFSM is capable of simulating a baseline scenario of the current status of the Gulf of Mexico shrimp fishery and changes of these fishery management policies. The limitation of this study is the lack of available data on U.S. imports and the Atlantic shrimp by size class. With this information, future studies may be in a better position to ascertain these effects on ex-vessel prices of different size classes.

References

Adams, C.M. 1993. A Preliminary Assessment of Ex-vessel Price Movements in the South Atlantic Rock Shrimp Fishery. *Report to the Staff of the South Atlantic Regional Fisheries Management Council.* November 23, 1993.

Adams, C.M., R.J. Prochaska, and T.H. Spreen. 1987. Price Determination in the U.S. Shrimp Market. *Southern Journal of Agricultural Economics* 19(2):103–11.

Blomo, V.J., J.P. Nichols, W.L. Griffin, and W.E. Grant. 1982. Dynamic Modeling of the Eastern Gulf of Mexico Shrimp Fishery. *American Journal of Agricultural Economics* 64:475–82.

Chui, M.K. 1980. Ex-vessel Demand by Size for the Gulf Shrimp. Master's thesis. Texas A&M University.

Doll, J.P. 1972. An Econometric Analysis of Shrimp Ex-vessel Prices. *American Journal of Agricultural Economics* 54:431–40.

Grant, W.E. and W.L. Griffin. 1979. A Bioeconomic Model of the Gulf of Mexico Shrimp Fishery. *Transactions of the American Fisheries Society* 108:1–13.

Greenberg, J.A., M. Herrmann, and J. McCracken. 1995. An International Supply and Demand Model for Alaska Snow Crab. *Marine Resource Economics* 10(3):231–46.

Greene, W.H. 1993. *Econometric Analysis,* 2nd ed. Ontario: Macmillan Publishing Co.

Hopkins, J.C. 1983. An Econometric Analysis of the U.S. Shrimp Industry. Master's thesis. Texas A&M University.

Judge, G.G., R.C. Hill, W.E. Griffiths, H. Luthkepohl, and T.C. Lee. 1988. *Introduction to the Theory and Practice of Econometrics,* 2nd ed. New York: John Wiley & Sons, Inc.

Keithly, W.R. Personal Communication. 6 June 1996.

___. Personal Communication. 7 November 1996.

Keithly, W.R., K.J. Roberts, and J.M. Ward. 1993. Effects of Shrimp Aquaculture on the U.S. Market: An Econometric Analysis. *Aquaculture Models and Economics.* Boulder, CO: Westview Press, Inc.

Kmenta, J. 1986. *Elements of Econometrics,* 2nd ed. New York: Macmillan Publishing Co.

Lea, J.D., and J.S. Shonkwiler. 1988. Misspecification in Simultaneous Systems: An Alternative Test and Its Application to a Model of the Shrimp Market. *Southern Journal of Agricultural Economics* 20(2):65–72.

O'Connell, J.D. 1988. Determinants of Demand in the U.S. Shrimp Market. Master's thesis. University of Rhode Island.

Roberts, J.K., W.R. Keithly, and C.M. Adams. 1990. The Impact of Imports, Including Farm-Raised Shrimp, on the Southeastern Shrimp Processing Sector. *Final Report to Gulf & South Atlantic Fisheries Development Foundation.* Food and Resource Economics Department, University of Florida.

SHAZAM *User's Reference Manual Version 7.0.* 1993. ISBN 0-07-069862-7. New York: McGraw-Hill.

Thompson, E.M., and K.J. Roberts. 1983. An Econometric Analysis of the U.S. Shrimp Market. Center for Wetland Resources, Louisiana State University, Baton Rouge, LA.

Upton, H.F., P. Hoar, and M. Upton. 1992. *The Gulf of Mexico Shrimp Fishery: Profile of a Valuable National Resource.* Washington DC: Center for Marine Conservation.

U.S. Department of Commerce. 1982–96. Economics and Statistics Administration. Bureau of Economic Analysis. *Survey of Current Business.* Washington DC: Government Printing Office.

___. 1981–95. Economics and Statistics Administration. Bureau of the Census. *Current Business Reports: Monthly Retail Trade.* Washington DC: Government Printing Office.

___. 1996. Economics and Statistics Administration. Bureau of the Census. *Monthly Estimates of the U.S. Population.* Washington DC: Government Printing Office.

___. 1980–95, National Oceanographic and Atmospheric Administration. National Marine Fisheries Service. *Fisheries of the United States.* Washington DC: Government Printing Office.

Vondruska, J. 1996. Southeast Shrimp Fishery Market Trends, 1995 and early 1996. *National Marine Fisheries Service.*