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On Estimating the Impact of the Deepwater Horizon Tragedy on the U.S. Frozen Seafood Market: A Conditional Almost Ideal Demand System Approach

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Abstract: The present study addresses the impact of the Deepwater Horizon event on the U.S. frozen fish and shellfish markets. Given a demand system approach, trends in consumption were carefully measured and tested while controlling for own price, cross price, and conditional expenditure effects as well as autocorrelation. Consumption trends beginning the first week of the data set were unaltered by the event. Moreover, the effect of the event was not statistically significant in either demand system. The aggregate national data for the grocery store distribution channel, which includes mostly imported seafood and some domestic aquaculture-sourced seafood, likely contributes to these findings of lack of avoidance behavior.

Keywords: Almost Ideal Demand System; Deepwater Horizon; frozen seafood market; retail scanner data

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1. Introduction

On April 20, 2010 the Deepwater Horizon exploded then later sank causing a disruption to economies dependent on the Gulf of Mexico. Vickner [1] notes that it was the largest oil spill on record, not only in the Gulf of Mexico but also globally, having leaked nearly five million barrels. For example, it was orders of magnitude larger than the iconic 1989 Exxon Valdez oil spill in Alaska's Prince William Sound. The Deepwater Horizon event was also widely covered in the news for several months, initially with coverage of the burning oil rig, loss of life, and injured workers, and later coverage of the extensive cleanup efforts which included images of oil-covered birds and beaches. This environmental disaster resulted in the largest corporate settlement in U.S. history of nearly $21 billion. In addition to the record-setting $5.5 billion of fines under the U.S. Clean Water Act, damages were also paid to five states and 400 local governments [1].

The primary empirical objective of this study is to test for any discernable consumer avoidance behavior due to the event using a theoretically-consistent, empirically-tractable conditional demand system and data for the U.S. frozen fish and shellfish markets. Given the sheer magnitude of the event, analysis of this market warrants investigation. Since most of the products in this market are either imported or sourced from aquaculture production systems, it is a natural experiment involving the demand side of the market. Own price, cross price, and conditional expenditure elasticities, as well as controls for system-wide autocorrelation, are also presented and discussed.

The remainder of this paper is organized as follows. Section 2 presents the literature review, Section 3 outlines the model development, Section 4 describes the data, Section 5 discusses the empirical results, and Section 6 summarizes the paper and provides directions for future research initiatives.

2. Literature Review

To analyze the market demand for frozen seafood in the grocery store distribution channel, we build upon a well-developed microeconomic model of consumer choice that incorporates the role information plays in individual decision-making [2–8]. In particular, we extend and modify Swartz and Strand's [2] seminal work which assessed the impact of information regarding harvest bans on the demand for non-contaminated oysters. Teisl, Bockstael and Levy [9] used Foster and Just's [10] framework in conjunction with Deaton and Muelbauer's [11] Almost Ideal Demand System to investigate the impact of changing product information. Their general theoretical approach is adopted and modified here.

As previously mentioned, an empirical objective of this paper is to determine the impact of price changes of frozen seafood in the grocery store distribution channel while controlling for the Deepwater Horizon event. As discussed in Singh, Dey, and Surathkal [12], this segment of the U.S. retail seafood industry composes 36% of all seafood purchased in the food-at-home distribution channel excluding fresh, random weight items. Of particular interest for this study are substitution effects [13–15]. For example, if substitution effects were present, a price decrease in frozen catfish would lead to an inward or leftward shift in the demand for frozen perch, hence decreasing the quantity of perch sold, ceteris paribus. This effect must be controlled for properly to empirically disentangle it from any possible effects of the Deepwater Horizon tragedy. Finally, Smith et al. [16] and Asche, Guttormsen, and Tveteras [17] discussed the importance of the role of aquaculture on the overall market for seafood; the quality of inland aquaculture sourced seafood would not be affected by the Deepwater Horizon tragedy.

3. Model Development

The empirical demand system stems from a well-developed microeconomic model of consumer choice. Let x_i be the quantity consumed of retail frozen seafood product i, where $i = 1, \ldots, n$. Then x is a $n \times 1$ vector with elements x_i. Further, let q_i be the elements of the $n \times 1$ vector q, where q_i is the perceived quality of good x_i. Perceived product quality may be influenced by a myriad of non-price, non-income factors including, but not limited to, product labels, the media, food safety recalls, advertising, brand image, and an event such as the sinking of the Deepwater Horizon. Let s_i represent a non-price, non-income information index characterizing the quality of seafood product i such that $\frac{\partial q_i}{\partial s_i} < 0$; higher levels of bad news lead to a lower level of perceived quality. More generally, we let the vector q be a function of the vector s, or $q(s)$.

As is the case for most applied demand studies, data is typically unavailable to construct a complete demand system [18]. Thus, we assume the consumer's utility function is weakly separable between retail frozen seafood and all other goods. In our problem, the individual consumer chooses x to maximize:

$$U(x, q) \tag{1}$$

subject to the linear budget constraint:

$$p'x = M \tag{2}$$

where $U(\ )$ is the utility function, p' is a $1 \times n$ vector of prices of retail frozen seafood, and M is total expenditure for retail frozen seafood.

The solution to the consumer's problem results in a vector of n Marshallian or uncompensated demand functions

$$x^m(p, M, q) \tag{3}$$

with the usual properties [18]. Because perceived quality is a function of the information index or $q(s)$, we may express the Marshallian demand functions as

$$x^m(p, M, s) \tag{4}$$

so that the Marshallian demands now include a vector of shift parameters based on the information index.

Substituting Equation (4) into the utility function, we obtain the indirect utility function $V(p, M, s)$. Others in the literature begin their model development with essentially this expression for the indirect utility function [19]. Inverting the indirect utility function, we obtain the consumer's expenditure function

$$E(p, u, s) \tag{5}$$

By applying Shephard's lemma to the expenditure function

$$\frac{\partial E(p, u, s)}{\partial p} = x^h(p, u, s) \tag{6}$$

we obtain the n Hicksian demand functions and express them in expenditure share form in the $n \times 1$ vector w. The presence of the informational shift variables s in Equation (6) presents a difficult problem when estimating w.

We represent w using the corrected Linear Approximate Almost Ideal Demand System (LA-AIDS) model [11,20]. The expenditure share (w_i) for the i^{th} frozen seafood product, is given by

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln\left(\frac{M}{P}\right) \tag{7}$$

where the usual unobservable, nonlinear AIDS price index is replaced by the loglinear analog of the Laspeyres price index for constant base period shares w^0 [20]. It is given by

$$\ln(P) = \sum_{i=1}^{n} w_i^0 \ln(p_i) \tag{8}$$

The informational shift variables are incorporated into the α_i parameters as

$$\alpha_i = \varnothing_i + \theta_{1i}(\text{Trend}) \tag{9}$$

For the singular, conditional LA-AIDS model, the adding up conditions are given by

$$\sum_{i=1}^{n} \varnothing_i = 1, \sum_{i=1}^{n} \theta_{1i} = 0, \sum_{i=1}^{n} \gamma_{ij} = 0\ \forall j, \text{ and } \sum_{i=1}^{n} \beta_i = 0 \tag{10}$$

Homogeneity and symmetry are, respectfully, imposed on the model with

$$\sum_{i=1}^{n} \gamma_{ij} = 0\ \forall i \text{ and } \gamma_{ij} = \gamma_{ji}\ \forall_i \neq j \tag{11}$$

The use of translating and scaling techniques have long been used to incorporate shift variables such as demographics into singular expenditure systems without violating Closure Under Unit Scaling (CUUS) [21,22]. The notion of CUUS is maintained when the estimated parameters, such as the usual $\propto$, γ and β parameters in the Almost Ideal Demand System [11], do not depend on the data's scaling, especially the scaling of the data related to the shift variables themselves [6,23].

3.1. Econometric Estimation and Autocorrelation Correction in A Singular System

Following Berndt and Savin [24], with appropriate substitutions and addition of subscripts representing weekly time periods, the demand model of retail frozen seafood given by Equation (7) may be rewritten more compactly as

$$w_t = \Pi z_t + v_t \tag{12}$$

where w_t is a $n \times 1$ vector of conditional expenditure shares of frozen seafood, Π is a $n \times K$ matrix of unknown parameters, z_t is $K \times 1$ vector of explanatory variables, and v_t is a $n \times 1$ vector of stochastic disturbances governed by the following process

$$v_t = Rv_{t-1} + \varepsilon_t \tag{13}$$

for time $t = 2, \ldots, T$, R is a $n \times n$ matrix of unknown parameters, and ε_t is a $n \times 1$ vector of residuals. Further it is assumed $\{\varepsilon_t\}$ is distributed *iid* $N(0, \Sigma)$ for $t = 2, \ldots, T$.

Let t' be a $1 \times n$ vector of ones. Because the demand model of retail frozen seafood is singular (i.e., its shares sum to one), $t' w_t = 1$ for $t = 1, \ldots, T$. The adding up conditions also imply $t'\Pi = [1\ 0\ 0 \ldots 0]$, $t' v_t = 0$ for $t = 1, \ldots, T$ and, since v_{t-1} and ε_t are independent, $t'R = k'$. The final result indicates the n column sums of R equal the same constant.

The autocorrelation correction procedure for singular equation systems as developed by Berndt and Savin [24] is quite flexible and subsumes several interesting special cases. When the $n \times n$ elements of matrix R are set to zero, this represents the case of no autocorrelation such that $v_t = \varepsilon_t$ and $w_t = \Pi z_t + \varepsilon_t$. For the present data set this assumption is implausible and, hence, introduces an omitted variable bias in the matrix of parameter estimates Π. If the n elements on the diagonal of matrix R are restricted to be the same constant and the off-diagonal elements are restricted to all be zeros, this single parameter estimate for serial correlation correction will equal k' since $t'R = k'$. This parsimonious assumption is maintained for the present study. It is noted R may be kept in its most general form with n^2 unique elements. For the present study, the full matrix over-parameterizes the model.

In this empirical application, consider the case of four frozen retail fish products ordered as follows: catfish, tilapia, perch, and all other fish. It is noted the data supplier combines both freshwater and saltwater perch into one seafood type. Also, in this second empirical demand application, we considered the case of four frozen retail shellfish products ordered as follows: shrimp, crawfish, mussels, and all other shellfish. For each model, this results in $n = 4$ conditional expenditure share equations. Since the system is singular as the shares sum to one, the 4^{th} equation is dropped from the estimation. Equations (12) and (13), with the 4^{th} equation dropped may be rewritten as

$$w_t^4 = \Pi_4 z_t + v_t^4 \tag{14}$$

and

$$v_t^4 = R_4 v_{t-1}^4 + \varepsilon_t^4 \tag{15}$$

for $t = 2, \ldots, T$. Since R_4 is now a 3×4, Equations (14) and (15) are not estimable. Recognizing $t' v_t = 0$, this is remedied by Berndt and Savin [24] by the following transformation

$$\overline{R}_4 = \begin{bmatrix} (R_{11} - R_{14}) & (R_{12} - R_{14}) & (R_{13} - R_{14}) \\ (R_{21} - R_{24}) & (R_{22} - R_{24}) & (R_{23} - R_{24}) \\ (R_{31} - R_{34}) & (R_{32} - R_{34}) & (R_{33} - R_{34}) \end{bmatrix} \tag{16}$$

so that $\overline{R}_4$ is now a 3×4. Now the $n - 1$ column sums in $\overline{R}_4$ each equal zero. Substituting $\overline{R}_4$ into Equation (15) we obtain

$$v_t^4 = \overline{R}_4 v_{t-1}^4 + \varepsilon_t^4 \tag{17}$$

Further substituting Equation (17) into Equation (14), we obtain the estimable, theoretically consistent, conditional Almost Ideal Demand System model of retail frozen seafood as given by

$$w_t^4 = \overline{R}_4 w_{t-1}^4 + \Pi_4 z_t - \overline{R}_4 \Pi_4 z_{t-1} + \varepsilon_t^4 \tag{18}$$

for $t = 2, \ldots, T$. Using the PROC MODEL routine in the SAS 9.4 ETS module, we jointly estimate the parameters in Π_4 and $\overline{R}_4$ using nonlinear seemingly unrelated regressions (SUR) [25]. An iterated SUR approach was not used due to lack of stability in the likelihood ratio tests for non-price, non-income informational shifters. However, it should be noted the iterated SUR and SUR led to very similar parameter estimates and levels of statistical significance with the former being only slightly more efficient. This model is highly nonlinear since Π_4 and $\overline{R}_4$ enter into Equation (18) as a product. It is noted $\{\varepsilon_t\}$ is distributed *iid* $N(0, \Sigma)$ for $t = 2, \ldots, T$ [24,25]. Finally, as mentioned previously, $\overline{R}_4$ is given in its diagonal form for first-order autocorrelation correction. The parameter estimates for Π_4 and $\overline{R}_4$ for both frozen fish and frozen shellfish are reported and discussed in the Empirical Results section.

3.2. Hypothesis Testing of Consumer Response to Information

Germane to this study is the cross-equation hypothesis test in which the three equations manifested in Equation (18) are estimated with Equation (9) versus the restricted model where Equation (9) is replaced with

$$\alpha_i = \varnothing_i \tag{19}$$

for $i = 1, \ldots, 3$ such that $\theta_{1i} = 0$. The restricted model imposes the null hypothesis that the trend has no impact on the aggregate consumer behavior in the market for retail frozen seafood. This test is considered to be far superior to a simple inspection of the parameter by parameter asymptotic t-statistics, especially in small samples. Using any single-equation approach, it is not possible to comprehensively test information effects on the demand system overall. The procedure used to test this cross-equation restriction is a likelihood ratio test [25]. The likelihood ratio statistic for our model is given by

$$LR = S\left(\hat{\pi}_R, \hat{\Sigma}_U\right) - S\left(\hat{\pi}_U, \hat{\Sigma}_U\right) \tag{20}$$

where $S(\ )$ is the objective function of the SUR multiplied by the number of time periods net of any lags, $S(\hat{\pi}_R, \hat{\Sigma}_U)$ is $S(\ )$ for the estimated restricted model where the covariance matrix is held constant from the estimated unrestricted model, and $S(\hat{\pi}_U, \hat{\Sigma}_U)$ is $S(\ )$ for the unrestricted model. The test statistic is distributed asymptotically chi-square with $K^U - K^R$ degrees of freedom where K^U is the number of estimated parameters in the unrestricted model and K^R is the number of estimated parameters in the restricted model. If LR is less than the chi-square critical value for some alpha level of significance then we fail to reject the null hypothesis and conclude the restricted and unrestricted models are statistically no different. The outcome of the hypothesis test would quantify whether or not the trend affected the demand for the frozen seafood products. In addition to this test, the time trend in Equation (9) is replaced with an indicator variable set to one during the entire duration of the Deepwater Horizon event and zero otherwise. Other informational shift variables could be incorporated into the model [7,8]. However, those tests are beyond the scope of the present study and the subject of future research.

4. Data Description

Using detailed, representative point-of-purchase scanner data, we estimated a conditional demand system. The Nielsen Company, a leading firm globally in the market for syndicated retail scanner data as well as media analysis, assembled the data set for this study. These data spanned the 156-week time frame from the Saturday ending 24 May 2008 through 14 May 2011. The data were aggregated by universal product code (UPC) into a useable weekly data set to investigate the retail demand for frozen unbreaded seafood. Gulf of Mexico major commercial seafood species include blue crab, crawfish, grouper, menhaden, mullet, oysters, red snapper, shrimp, stone crab, and tuna [26]. Hence there is reasonable coverage in the underlying scanner data of these species despite aggregations imposed by the Nielsen Company.

Descriptive statistics for the continuous variables in the unrestricted conditional demand system of frozen retail fish and shellfish are given in Tables 1 and 2, respectively. The parameter estimates of the unrestricted conditional demand system of retail frozen fish and shellfish may be found in Tables 3 and 4, respectively. Tables 5 and 6 contain the estimated Marshallian price elasticities and the conditional expenditure elasticities for fish and shellfish, respectively.

5. Empirical Results

The unrestricted conditional fish demand system outlined in Table 3 exhibits reasonable properties for the given data set and application. Four of the six price parameters, all three of the conditional expenditure parameters, and two of the three intercepts are statistically significant (ranging from $p < 0.01$ to $p < 0.10$). As for non-price and non-expenditure shifters, all three of the trend parameters are statistically significant ($p < 0.01$). The Durbin Watson statistics indicate the parsimonious version of the Berndt-Savin [24] autocorrelation correction procedure is successful in purging serial correlation from the model; incidentally, the autocorrelation parameter estimate is statistically significant ($p < 0.01$). While the adjusted R^2 measures appear somewhat lower than desired, it is emphasized the expenditure shares are extremely volatile at the weekly level so the levels of this diagnostic are not entirely unexpected. Stability or robustness of the parameter estimates, significance of the parameter estimates, and stability of the likelihood ratio tests are quite impressive for this model, hence outweighing the importance of the adjusted R^2 values. Similar results for parameter estimates and diagnostic measures are observed for unrestricted conditional shellfish demand system in Table 4.

Moreover, we reject the null hypothesis of no trend effect (i.e., $\theta_{11} = \theta_{12} = \theta_{13} = 0$) at the 5% level of significance in the fish demand model; the likelihood ratio test statistic of 86.8 far exceeds the critical value of 7.8. Similarly, in the shellfish demand model, we also reject the null hypothesis of no trend effect at the 5% level of significance; the likelihood ratio test statistic of 20.6 again exceeds the critical value of 7.8. This test is considered to be far superior to a simple inspection of the parameter by parameter asymptotic *t*-statistics, especially in small samples. Using any single-equation approach, it is not possible to comprehensively test information effects on the demand system overall. It is noted that the results presented here designate the trend in each equation beginning in the first week of the data set, not the week of the Deepwater Horizon explosion. However, these test results were robust to starting points of the trends corresponding to the various key event dates of the Deepwater Horizon tragedy [1]. Hence, the trends were unaltered and continued on their respective trajectories autonomous of Deepwater Horizon event. This finding of lack of avoidance behavior is not surprising. The aggregate, national data set for the grocery store distribution channel, which includes mostly imported seafood and some domestic aquaculture-sourced seafood, likely contributes to this finding. The additional likelihood ratio test results are available upon request from the author.

Furthermore, another system-wide hypothesis test was conducted where the time trend in Equation (9) was replaced with an indicator variable set to 1 during the entire duration of the Deepwater Horizon event and 0 otherwise. Given media coverage was nearly constant and nonstop in this event time frame, the indicator variable approach was appropriate. We fail to reject the null hypothesis of no event effect (i.e., $\theta_{11} = \theta_{12} = \theta_{13} = 0$) at the 5% level of significance in the fish demand model; the likelihood ratio test statistic of 6.7 was less than the critical value of 7.8. Similarly, in the shellfish demand model, we also fail to reject the null hypothesis of no event effect at the 5% level of significance; the likelihood ratio test statistic of 0.2 was less than the critical value of 7.8.

Finally, in Tables 5 and 6, we report the estimated Marshallian price and conditional expenditure elasticities for fish and shellfish, respectively. Alston, Foster, and Green [27] outlined functional forms of LA-AIDS elasticities used herein. The uncompensated or Marshallian own and cross price elasticities for fish in Table 5 exhibit reasonable direction and magnitude in most cases. For example, the own price elasticity of demand for perch is −2.1179; thus, a 1% increase in the price of perch results in a 2.1179%

decrease in the quantity demanded of perch. While the own price elasticity of demand is elastic for perch, it is inelastic for catfish, tilapia, and the 'all other fish' aggregated category. The cross price elasticity of demand between perch and catfish in the perch equation is 0.4179; thus a 1% increase in the price of catfish results in a 0.4179% increase in the quantity demanded of perch. Hence, these results indicate a substitute relationship between perch and catfish. The conditional expenditure elasticities each show the rates of segment growth as the frozen fish category expenditures rise. For example, a 1% increase in category expenditures results in a 1.1774% increase in the quantity demanded of perch. Similar results for the estimated Marshallian price and conditional expenditure elasticities are observed for shellfish in Table 6.

6. Summary and Future Directions

The triple bottom line of the sustainability paradigm (i.e., people, planet, profit) helps keep the impact of events such as the Deepwater Horizon tragedy top of mind and gives a study such as this important context. The present study addresses the economic impacts of this environmental event on the U.S. frozen fish and shellfish markets. Given a demand system approach, trends in consumption were carefully measured and tested while controlling for own price, cross price, and conditional expenditure effects as well as autocorrelation. Consumption trends beginning the first week of the data set were unaltered by the event. These test results were robust to starting points of the trends corresponding to the various key event dates of the Deepwater Horizon tragedy [1]. Moreover, another system-wide hypothesis test was conducted where the consumption time trend was replaced with an indicator variable set to 1 during the entire duration of the Deepwater Horizon event and 0 otherwise. Given media coverage was nearly constant and nonstop in this event time frame, the indicator variable approach was appropriate. We found no event effects in either the fish or shellfish demand models. The aggregate, national data set for the grocery store distribution channel, which includes mostly imported seafood and some domestic aquaculture-sourced seafood, likely contributes to this finding of lack of avoidance behavior.

More precise data for the restaurant distribution channel within the Gulf Coast region could prove insightful for testing hypotheses regarding consumption trends for specific fish and shellfish products immediately following the sinking of the Deepwater Horizon. This is an area for future research. Given the approach taken herein, it is possible to establish economic boundaries of the impact of an event, which has implications for making future damage estimates of other food market disruptions. This is also an area for future inquiry.

Table 1. Descriptive statistics of selected fish demand system variables.

	Mean	Standard Deviation
Expenditure Shares		
Catfish	0.0639	0.0095
Tilapia	0.3304	0.0428
Perch	0.0248	0.0058
Other Fish	0.5809	0.0414
Prices		
Catfish	3.2919	0.1507
Tilapia	3.9085	0.2448
Perch	4.7335	0.1977
Other Fish	5.0994	0.1703

Note: Based on 156 consecutive weekly observations. All products in U.S. dollars per pound.

Table 2. Descriptive statistics of selected shellfish demand system variables.

	Mean	Standard Deviation
Expenditure Shares		
Shrimp	0.8919	0.0113
Crawfish	0.0128	0.0036
Mussels	0.0032	0.0007
Other Shellfish	0.0922	0.0103
Prices		
Shrimp	6.5189	0.2492
Crawfish	8.7910	0.5210
Mussels	3.2151	0.2242
Other Shellfish	6.1776	0.4684

Note: Based on 156 consecutive weekly observations. All products in U.S. dollars per pound.

Table 3. Conditional Linear Approximate Almost Ideal Demand System (LA-AIDS) fish model parameter estimates.

	Catfish	Tilapia	Perch
Prices			
Catfish	0.0651 *** (0.0214)	−0.0116 (0.0124)	0.0107 (0.0067)
Tilapia		0.0841 ** (0.0332)	0.0075 * (0.0046)
Perch			−0.0276 *** (0.0055)
Expenditure	0.0237 *** (0.0043)	0.0682 *** (0.0110)	0.0044 *** (0.0015)
Intercept	−0.3443 *** (0.0747)	−0.8000 *** (0.00003)	−0.0080 (0.1683)
Trend	−0.0001 *** (0.0001)	0.0006 *** (0.0282)	−0.0001 *** (0.00001)
Autocorrelation	0.3789 *** (0.0463)	0.3789 *** (0.0463)	0.3789 *** (0.0463)
Durbin Watson	1.8289	2.3769	2.2110
Adjusted R^2	0.2424	0.7266	0.7619

Note: Symmetry and homogeneity are imposed. Standard error in parentheses. Results are corrected for first-order autocorrelation using the $\overline{R}_4$ matrix. Single, double, and triple asterisks (*) denote statistical significance at the 0.10, 0.05, and 0.01 levels, respectively.

Table 4. Conditional LA-AIDS shellfish model parameter estimates.

	Shrimp	Crawfish	Mussels
Prices			
Shrimp	0.0032 (0.0259)	−0.0058 (0.0060)	−0.0026 * (0.0015)
Crawfish		−0.0194 *** (0.0050)	0.0004 (0.0011)
Mussels			−0.0035 *** (0.0008)
Expenditure	0.0145 *** (0.0055)	−0.0031 ** (0.0014)	−0.0015 *** (0.0003)
Intercept	0.6916 *** (0.0871)	0.1083 *** (0.0222)	0.0333 *** (0.0055)
Trend	−0.0001 ** (0.00004)	0.00004 *** (0.00001)	0.000008 *** (0.000002)
Autocorrelation	0.5627 *** (0.0458)	0.5627 *** (0.0458)	0.5627 *** (0.0458)
Durbin Watson	2.2443	1.6204	2.4695
Adjusted R^2	0.1664	0.6518	0.7637

Note: Symmetry and homogeneity are imposed. Standard error in parentheses. Results are corrected for first-order autocorrelation using the $\overline{R}_4$ matrix. Single, double, and triple asterisks (*) denote statistical significance at the 0.10, 0.05, and 0.01 levels, respectively.

Table 5. Estimated price and expenditure elasticities for fish.

	Catfish	Tilapia	Perch	Other Fish
Uncompensated				
Catfish	−0.0053	−0.3043	0.1574	−1.2185
Tilapia	−0.0484	−0.8137	0.0175	−0.3617
Perch	0.4179	0.2424	−2.1179	0.2802
Other Fish	−0.0998	−0.0828	0.0205	−0.6722
Expenditure	1.3706	1.2063	1.1774	0.8343

Note: The uncompensated price elasticities are defined by $E_{ij} = -\partial + \left(\frac{\gamma_{ij}}{w_i}\right) - \left(\frac{\beta_i}{w_i}\right)w_j$, where γ and β are defined above, expenditure shares are taken at their sample means, and δ is the Kronecker delta. The conditional expenditure elasticity $(E_{i,x})$ is given by $E_{i,x} = 1 + \frac{\beta_i}{w_i}$.

Table 6. Estimated price and expenditure elasticities for shellfish.

	Shrimp	Crawfish	Mussels	Other Shellfish
Uncompensated				
Shrimp	−1.0110	−0.0067	−0.0030	0.0044
Crawfish	−0.2345	−2.5103	0.0344	1.9542
Mussels	−0.3922	0.1422	−2.0937	1.8268
Other Shellfish	0.1524	0.2695	0.0616	−1.3763
Expenditure	1.0163	0.7562	0.5170	0.8927

Note: The uncompensated price elasticities are defined by $E_{ij} = -\partial + \left(\frac{\gamma_{ij}}{w_i}\right) - \left(\frac{\beta_i}{w_i}\right)w_j$, where γ and β are defined above, expenditure shares are taken at their sample means, and δ is the Kronecker delta. The conditional expenditure elasticity $(E_{i,x})$ is given by $E_{i,x} = 1 + \frac{\beta_i}{w_i}$.

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References

1. Vickner, S.S. Seafood safety and marketing: The case of the Deepwater Horizon tragedy. *Am. J. Agric. Econ.* **2016**, *98*, 643–647. [CrossRef]
2. Swartz, D.G.; Strand, I.E. Avoidance costs associated with imperfect information: The case of kepone. *Land Econ.* **1981**, *57*, 139–150. [CrossRef]
3. Smith, M.E.; van Ravenswaay, E.O.; Thompson, S.R. Sales loss determination in food contamination incidents: An application to milk bans in Hawaii. *Am. J. Agric. Econ.* **1988**, *70*, 513–520. [CrossRef]
4. Brown, D.J.; Schrader, L.F. Cholesterol information and shell egg consumption. *Am. J. Agric. Econ.* **1990**, *72*, 548–555. [CrossRef]
5. Wessells, C.R.; Miller, C.J.; Brooks, P.M. Toxic algae contamination and demand for shellfish: A case study of demand for mussels in Montreal. *Mar. Resour. Econ.* **1995**, *10*, 143–159. [CrossRef]
6. Piggott, N.E.; Marsh, T.L. Does food safety information impact US meat demand? *Am. J. Agric. Econ.* **2004**, *86*, 154–174. [CrossRef]
7. Kalaitzandonakes, N.; Marks, L.A.; Vickner, S.S. Media coverage of biotech foods and influence on consumer choice. *Am. J. Agric. Econ.* **2004**, *86*, 1238–1246. [CrossRef]
8. Kalaitzandonakes, N.; Marks, L.A.; Vickner, S.S. Sentiments and acts towards genetically modified foods. *Int. J. Biotechnol.* **2005**, *7*, 161–177. [CrossRef]
9. Teisl, M.F.; Bockstael, N.E.; Levy, A. Measuring the welfare effects of nutrition information. *Am. J. Agric. Econ.* **2001**, *83*, 133–149. [CrossRef]
10. Foster, W.; Just, R.E. Measuring welfare effects of product contamination with consumer uncertainty. *J. Environ. Econ. Manag.* **1989**, *17*, 266–283. [CrossRef]
11. Deaton, A.; Muelbauer, J. An almost ideal demand system. *Am. Econ. Rev.* **1980**, *70*, 312–326.
12. Singh, K.; Dey, M.M.; Surathkal, P. Analysis of a demand system for unbreaded frozen seafood in the United States using store-level scanner data. *Mar. Resour. Econ.* **2012**, *27*, 371–387. [CrossRef]

13. Eales, J.; Wessells, C.R. Testing separability of Japanese demand for meat and fish within differential demand systems. *J. Agric. Resour. Econ.* **1999**, *24*, 114–126.
14. Dedah, C.; Keithly, W.R.; Kazmierczak, R.F. An analysis of US oyster demand and the influence of labeling requirements. *Mar. Resour. Econ.* **2011**, *26*, 17–33. [CrossRef]
15. Chidmi, B.; Hanson, T.; Nguyen, G. Substitutions between fish and seafood products at the US national retail level. *Mar. Resour. Econ.* **2012**, *27*, 359–370. [CrossRef]
16. Smith, M.D.; Roheim, C.A.; Crowder, L.B.; Halpern, B.S.; Turnipseed, M.; Anderson, J.L.; Asche, F.; Bourillon, L.; Guttormsen, A.G.; Khan, A.; et al. Sustainability and global seafood. *Science* **2010**, *327*, 784–786. [CrossRef]
17. Asche, F.; Guttormsen, A.G.; Tveteras, R. Aquaculture—Opportunities and challenges. *Mar. Resour. Econ.* **2008**, *23*, 395–400. [CrossRef]
18. Varian, H. *Microeconomic Analysis*, 3rd ed.; W.W. Norton & Company: New York, NY, USA, 1992.
19. Teisl, M.F.; Roe, B.; Hicks, R.L. Can eco-labels tune a market? Evidence from dolphin-safe labeling. *J. Environ. Econ. Manag.* **2002**, *43*, 339–359. [CrossRef]
20. Moschini, G. Units of measurement and the Stone index in demand system estimation. *Am. J. Agric. Econ.* **1995**, *77*, 63–68. [CrossRef]
21. Pollak, R.A.; Wales, T.J. Demographic variables in demand analysis. *Econometrica* **1981**, *49*, 1533–1551. [CrossRef]
22. Lewbel, A. A unified approach to incorporating demographic or other effects into demand systems. *Rev. Econ. Stud.* **1985**, *52*, 1–18. [CrossRef] [PubMed]
23. Alston, J.M.; Chalfant, J.A.; Piggott, N.E. Incorporating demand shifters in the almost ideal demand system. *Econ. Lett.* **2001**, *70*, 73–78. [CrossRef]
24. Berndt, E.R.; Savin, N.E. Estimation and hypothesis testing in singular equation systems with autoregressive disturbances. *Econometrica* **1975**, *43*, 937–958. [CrossRef]
25. Gallant, A.R. *Nonlinear Statistical Models*; John Wiley and Sons: New York, NY, USA, 1987.
26. National Marine Fisheries Service. *Fisheries Economics of the United States, 2011. U.S. Department of Commerce, National Oceanic and Atmospheric Administration Technical Memorandum NMFS-F/SPO-118*; National Marine Fisheries Service: Silver Spring, MD, USA, 2012; pp. 1–175.
27. Alston, J.M.; Foster, K.A.; Green, R.D. Estimating elasticities with the linear approximate almost ideal demand system: Some Monte Carlo results. *Rev. Econ. Stat.* **1994**, *76*, 351–356. [CrossRef]