Price Elasticity of Individual Brand in Seafood Products: Interval Censored Data via Bayesian Method

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Selected Paper prepared for presentation at the Agricultural & Applied Economics Association's 2014 AAEA Annual Meeting, Minnesota, Minneapolis, July 27-29, 2014

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Introduction

Accurate analysis of the demand system with retail scanner data is important for U.S. seafood marketing industry to understand pricing decisions and marketing strategy. The detailed information of store-level scanner data on sales response for every type of packaged seafood products allows a systematic approach to purchase patterns, brand-related demand elasticities, the evaluation of promotional profitability, and so on. Especially, there are the increased interests in analyzing brand performance that charge different prices to exploit differences in consumer price sensitivity (Urband and Hauser, 1980). Several researches suggested that price elasticity varies from product to product and from brand to brand as well (Ainslie and Rossi, 1998; Dillon and Gupta, 1996; and Foxall and et al., 2013). This study focuses on price elasticities of demand for seafood products with particular attention to individual brand.

A wide variety of fish and shellfish products are available in the seafood market, however, about 55% of the seafood consumption from 2004 through 2012 was represented by three topmost products such as shrimp, canned tuna and salmon. These three products have staid the stable consumption around 4 pounds for shrimp, 3 pounds for canned tuna, and 2 pounds for salmon per capita even though total annual consumption of seafood products has been gradually declined in U.S. (Seafood Health Facts, 2013 and U.S. Census Bureau, 2011). In this study, we consider estimating demand elasticity of individual brand for frozen shrimp, salmon, and tilapia products sold at supermarkets. Canned tuna categorized into a dry food item is replaced with tilapia products. The U.S. consumption of tilapia products has dramatically increased in the last decade (National Fisheries Institute, 2011). The fairly stable consumption of shrimp and salmon products and the increasing consumption of tilapia products can suggest strategic brand investments for long-term in seafood marketing industry.

The further details of scanner data has provided useful information related to consumers' purchase pattern with marketing manager or decision makers. Censoring issue, however, can arise over a demand analysis with household-level or store-level scanner data due to zero purchase or sales of particular commodities (Tiffin and Arnoult, 2010). In order to deal with incomplete information of observations, Heien and Wessells (1990) applied the Amemiya's two-step method to estimate the almost ideal demand system (AIDS) with household data including zero consumption of particular food commodities. They found that the censored regression technique provided consistent and asymptotically efficient estimates with AIDS model. Since the store-level scanner data of seafood products used in this study often display zero sales of particular brands, we apply an interval censored approach to obtaining the accurate price elasticities of individual brand through a Bayesian approach.

The general objective of this study is to estimate demand elasticity for individual brand with non-censored store-level data and with censored data for frozen shrimp, salmon and tilapia. With non-censored data, the first specific objective is that a LA/AIDS model is estimated for ten brands selected by relatively high sales frequency and then price elasticities of the selected brands are computed in each product, respectively. The second specific objective is to estimate an LA/AIDS model with the interval censored data through a Bayesian method with Jeffreys prior and to compute price elasticities. Lastly, we compare price elasticities of the selected brands with non-censored data and censored data.

Data Discussion

Store-level scanner data provide useful information about the actual market shares and the impacts of individual brand's price and promotion policies. The store-level data used in here start from January 2009 through September 2012, provided by A.C. Nielsen. The acquired dataset displays information including description of particular products such as brand, size, form, and formula on 4 weeks sales. The data cover several types of seafood products over 52 markets in metropolitan areas. The types of store channels are categorized into three groups in accordance with the definition of Nielsen ScanTrack; drug stores, Food Drug and Mass (FDM) stores having at least 10,000 square feet of selling space, and superstores, independent grocers or food stores having an annual sales turnover of over $2 million. Seafood sales in drug stores are negligible and thus three types of stores are aggregated. Wal-Mart was excluded from retailers in the acquired scanner dataset. Figure 1 represents trends of total sales of shrimp, salmon, and tilapia products over 4 years. The volume of shrimp sales is bigger than other two products, but the trend of shrimp sales is less stable than other two products; salmon and tilapia. Figure 2 displays the behavior of total prices in shrimp, salmon, and tilapia products.

Ten brands for the frozen shrimp, salmon, and tilapia products are respectively selected in terms of relatively high sales frequency (Table1). The frequency of store brands is outstandingly higher than other brands; 66% market shares of store brands for shrimp, 29% for salmon, and 29% for tilapia over 4 years (2009-2012). It might imply that store brands play an important role in seafood marketing strategy. Sales or market shares of a particular brand are sensitive to distribution coverage and thus sales of branded products may be dramatically affected when a brand gains or loses a major market or expands into another geographic region (Aaker, 1996). Markets areas of 52 are aggregated and referred to as U.S. total in this paper. Since this study focuses on changes in price elasticities of individual brand, other details of seafood products such as the size (oz.), form are not considered.

Theoretical Framework

Almost Ideal Demand System

The almost ideal demand system (AIDS) of Deaton and Muellabuer (1980) are selected to estimate demand elasticities for individual brand of seafood products in this study since the model allows for an exact aggregation over specific class of preferences. The AIDS demand function in the share form for individual brand is written as:

$$(1) \qquad w_i = a_i + \sum_{j=1}^{n} \gamma_{ij} \log P_j + \beta_i \log\left(\frac{x}{P}\right)$$

where w_i represents the share of the ith brand, a_i, β_i, and γ_{ij} are parameters of the demand system, P_j is the price of the jth brand, x is total expenditure of the ith brand, and P is price index. Total expenditure of individual brand is expressed as:

$$(2) \qquad x = \sum_{i=1}^{n} P_i\, Q_i$$

where Q_i is sales quantity of the ith brand. The price index of P is computed by:

$$(3) \qquad \log P = a_0 + \sum_{i=1}^{n} a_i \log P_i + \frac{1}{2} \sum_{j=1}^{n} \sum_{i=1}^{n} \gamma_{ij} \log P_i \log P_j.$$

Linear Approximate Almost Ideal Demand System

The Stone's price index incorporated in the AIDS model is referred to as the linear approximate almost ideal demand system (LA/AIDS). Using the price index from equation (3) often raises empirical difficulties, especially when aggregated annual time-series data are used, and it common to use Stone's price index (P^*) instead of P (Green and Alston, 1990):

(4) $$lnP^* = \sum_{k=1}^{l} W_k \, lnP_k.$$

In this study, other information except for brands is aggregated in order to concentrate on brand performance in seafood products. Using a LA/AIDS model is more appropriate than using of the AIDS model.

Interval Censored Data

Tobit model (Tobin, 1958) and Amemiya model (1974) are popular methods for handing zero values of observations. Heien and Wessells (1990) applied Amemiy's (1974) censoring approach for estimating an AIDS model with household-level data to handle zero purchases of various items under consumer's budget. Tiffin and Arnoult (2010) proposed the infrequency of purchase model to deal with zero purchases of food commodities in the UK, using a Bayesian method of estimating multivariate sample selection models. In this study, even if brands are selected by relatively high sales frequency, there are significant amount of zero sales in particular brands in shrimp, salmon, and tilapia products. We adapt an interval censored approach for handling zero sales in the LA/AIDS model for the selected brands. The censored variable of sales quantities is expressed as:

(5) $$Q_i = \begin{cases} \dfrac{Q_i^*}{p(y_i|\theta)} & \text{if } y_i \neq 0 \\ 0 & \text{if } y_i = 0 \end{cases},$$

where Q_i is observed sales for each brand, $p(y_i|\theta)$ is the probability that sales are made, θ is a vector of parameter from logistic regression, and y_i is a binary variable that takes the value when sales occur, Q_i^* is latent sales variables related to the observed sales. The latent sales variable is computed by:

(6) $$Q_i^* = Q_i \cdot p(y_i|\theta).$$

In cases where no sales are made, Q_i^* has a non-zero value because it is replaced by the values estimated from the interval censored data. We observe a truncated value at censored time t_i based on a likelihood of the observed values. The likelihood function for sales quantities is expressed as:

(7) $$p(y_i|\theta) = \begin{cases} \phi(y_i|\theta) & \text{if } \mathrm{y_i} \text{ is uncensored} \\ S(y_{r,i-1}|\theta) - S(y_{l,i-1}|\theta) & \text{if } \mathrm{y_i} \text{ is interval censored} \end{cases},$$

where $S(\cdot)$ is a survival function, $S(\cdot) = P(T > t) = 1 - F(t)$ where $F(t)$ is a cumulative distribution function, $y_{r,i-1}$ is right censoring by one-lagged variable of y_{i-1}, and $y_{l,i-1}$ is left censoring by one-lagged variable of y_{i-1}.

Bayesian Approach with Jeffreys Prior

The Bayesian technique is added to data censoring procedure. When censored variables are chosen as dependent variables, the price elasticites that are produced by the AIDS model are the biased estimates of the true price elasticities of demand (Maddala, 1983). Through the Bayesian method, we obtain the expected estimates of the AIDS model by sampling from the posterior distribution of the parameter. With the likelihood function of sales data (either zero or non-zero sales) and non-informative priors, the posterior distribution of a parameter is computed. Jeffrey's prior as a non-informative prior is given by:

(7) $$\pi(\theta) \propto |I(\theta)|^{1/2}$$

where $I(\theta)$ is Fisher information matrix, and $-E\left[\frac{d^2 \log p(y_i|\theta)}{d\theta^2}\right]$.

Based on the expected estimates of the AIDS model simulated from Markov chain Monte Carlo (MCMC) procedure based on Jeffrey's prior, own-price elasticity for the selected brand are computed by:

(8) $$\bar{e}_i = -1 + \frac{\bar{\gamma}_{ij}}{\bar{w}_i} - \bar{\beta}_i,$$

where $\bar{\gamma}_{ij}$, $\bar{\beta}_i$, and $\bar{w}_i$ are the expected estimates of the draws from MCMC samples.

Results

Branded products can play an important role in seafood marketing strategy. In this paper, we estimate price elasticities for individual brand in frozen shrimp, salmon, and tilapia products to unveil new strategies for seafood market industry. In addition to price elasticity for the selected brands, we consider estimating price elasticity with promotion and without promotion.

Comparison of Uncensored and Interval Censored in Non-Promotion

Table 2 displays own-price elasticities of shrimp products in uncensored and interval censored data, R^2 for the goodness of fit, and proportion of zero sales for the selected brands when there is no promotion. The second column represents the percentage of zero sales in each brand. Except for store brands, there exit a significant amount $(< 50\%)$ of zero sales. From the own-price elasticities with uncensored data, we first check the sign of elasticities. Store brands, RED, and SWANDER have negative sign and the absolute value is less than 1, and these three brands are inelastic. For other brands, however, they have the positive sign of elasticities and exhibit Giffen behavior. With the interval censored data, the goodness of fit for the model is improved. Own-price elasticities are more inelastic in store brands, RED, and SWANDER having negative sign, but other brands still show Giffen behavior even with the interval censored data. Table 3 reports the results from salmon products. Like shrimp products, store brand is inelastic with uncensored data and it becomes more inelastic with interval censored data. Some of brands in salmon products also show Giffen behavior (positive sign of own-price elasticities). Table 4 reports the results from tilapia products. Unlike shrimp and salmon product, all brands display negative signs. The percentage of zero sales in branded tilapia products is relatively smaller than other two products. Own-price elasticity of store brand in tilapia is inelastic while WESTERN, HN, and RED are elastic (greater than 1).

Price elasticites of the selected brands are closely tied to market shares. Store brands in shrimp, salmon, and tilapia take a large portion of market shares. Inelastic store brands in own-price elasticities can suggest a new market strategy to seafood marketing industry.

Comparison of Uncensored and Interval Censored in Promotion

In this paper, we compare price elasticities with uncensored data and with interval censored data as well as with promotion and without promotion. In table 2, own-price elasticity for store brand is more elastic with promotion than without promotion. There might exit promotion effect on store brands, but not for other selected brands. Even with promotion, some of brands show Giffen behavior. For salmon and tilapia products, when comparing without promotion and with promotion, we found the sales of store brands are affected by promotions since own-price elasticities are more elastic than without promotion (Tables 3 and 4). However, there barely exit promotion effects on other chosen brands in shrimp, salmon, and tilapia products. Own-price elasticites are also supported by the results from the interval censored data.

The comparison of promotion and non-promotion effects on individual brand represents that sales of store brand are affected by promotion but not for other brands. The effects of promotion and non-promotion in the chosen brands indicate the role of store brands in seafood marketing strategy.

Implication and Discussion

The AIDS model with interval censored data via a Bayesian technique yields the improved goodness of fit and price elasticities of a particular brand (store brands) in shrimp, salmon, and tilapia products. Market shares of brands for shrimp, salmon, and tilapia are dominated by store brands. In addition, store brand have less amount of zero sales than other brands. The findings show that store brands can provide a new marketing strategy for a long-run in U.S. seafood marketing industry.

In this study, although we estimate the LA/AIDS model with an interval censored data to obtain the accurate price elasticities, a censoring approach is only focused on dependent sales quantities. Price of individual brand still remains uncensored.

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Table 1. Selected Brands for Shrimp, Salmon and Tilapia Products According to High Unit Sales Frequency during Given Period

Brand names	Market shares	Brand names	Market shares	Brand names	Market shares
Shrimp		*Salmon*		*Tilapia*	
Store Brands	66%	Store Brands	29%	Store Brands	29%
Eastern Fish	2.4%	Copper River Seafood	2.5%	Colorado Boxed Beef	2.9%
Frisco Food	2.1%	ORCA Bay Food	4.2%	Frisco Food	5.3%
H N Foods International	2.1%	Pacific Seafood	4.2%	H N Foods International	3.3%
ORE CAL	2.2%	Sea Star Seafood	2.5%	Sea Star Seafood	2.0%
Red Chamber	9.5%	Red Chamber	6.7%	Red Chamber	3.3%
State Fish	2.4%	The Fishin	3.2%	The Fishin	3.3%
Tai Foong International	2.5%	Trident Seafood	2.5%	Swander Pace	4.5%
Thai Union	2.6%	YIHE	5.3%	Ouirch Foods	2.4%
Mazzetta	2.2%	Sea Star Seafood	2.5%	Western Edge Seafood	2.9%

Table 2. Comparison of AIDS Model with Uncensored vs. Interval Censored Data for Shrimp

Brands (*Non-promo*)	Percentage (%) of zero sales	R^2		Own-price elasticity	
		Uncensored	Interval Censored	Uncensored	Interval Censored
CTL	32.78	0.76	0.83	-0.88	-0.82
EASTERN	89.53	0.20	0.53	0.94	0.83
FRISCO	91.36	0.33	0.58	0.41	0.31
MAZZETTA	71.47	0.19	0.32	0.80	0.11
ORE	90.26	0.09	0.12	0.75	0.56
RED	92.20	0.61	0.74	-0.60	-0.41
STATE	92.90	0.11	0.31	0.72	0.43
TAI	91.22	0.13	0.43	1.44	0.41
THAI	92.21	0.23	0.63	0.62	0.56
SWANDER	91.08	-	-	-0.58	-0.23
Brands (*Promo*)					
CTL	32.78	0.76	0.83	-0.89	-0.89
EASTERN	89.53	0.18	0.61	0.84	0.62
FRISCO	91.36	0.29	0.59	0.57	0.21
MAZZETTA	71.47	0.23	0.34	0.94	0.19
ORE	90.26	0.06	0.17	1.73	0.63
RED	92.20	0.60	0.71	-0.52	0.56
STATE	92.90	0.15	0.35	0.99	-0.19
TAI	91.22	0.07	0.17	2.14	0.62
THAI	92.21	0.27	0.67	0.75	0.59
SWANDER	91.08	-	-	0.0004	-0.04

Table 3. Comparison of AIDS Model with Uncensored vs. Interval Censored Data for Salmon

Brands (*Non-promo*)	Percentage (%) of zero sales	R^2		Own-price elasticity	
		Uncensored	Interval Censored	Uncensored	Interval Censored
CTL	36.29	0.78	0.86	-0.89	-0.87
COPPER	93.75	0.19	0.49	-5.41	-4.41
ORCA	92.77	0.43	0.51	0.48	0.43
RED	82.80	0.46	0.66	-0.26	-0.13
SEA	94.32	0.23	0.53	3.64	2.45
SWANDER	90.42	0.45	0.65	1.12	1.11
FISHIN	89.81	0.72	0.84	-0.47	-0.12
YIHE	82.92	0.63	0.78	-0.50	-0.34
TRIDENT	91.21	0.48	0.65	0.96	0.85
PACIFIC	97.35	-	-	-1.53	-1.01
Brands (*Promo*)					
CTL	36.29	0.92	0.92	-0.93	-0.91
COPPER	93.75	0.36	0.56	-0.83	-0.78
ORCA	92.77	0.65	0.65	-0.49	-0.32
RED	82.80	0.82	0.72	-0.71	-0.65
SEA	94.32	0.83	0.61	-2.74	-2.11
SWANDER	90.42	0.40	0.72	-0.33	-0.21
FISHIN	89.81	0.97	0.86	-0.76	-0.54
YIHE	82.92	0.77	0.79	-0.83	-0.61
TRIDENT	91.21	0.91	0.71	0.20	0.16
PACIFIC	97.35	-	-	0.43	0.29

Table 4. Comparison of AIDS Model with Uncensored vs. Interval Censored Data for Tilapia

Brands (Non-promo)	Percentage (%) of zero sales	R^2		Own-price elasticity	
		Uncensored	Interval Censored	Uncensored	Interval Censored
CTL	34.94	0.86	0.92	-0.89	-0.74
WESTERN	81.16	0.12	0.54	-1.11	-1.08
FRISCO	57.58	0.69	0.75	-0.85	-0.67
SEA	75.85	0.41	0.62	-0.65	-0.34
HN	89.39	0.17	0.57	-1.41	-1.07
RED	87.88	0.22	0.51	-3.62	-3.19
SWANDER	82.20	0.41	0.69	-0.43	-0.54
COLORADO	74.15	0.25	0.53	-1.53	-0.69
FISHIN	64.30	0.61	0.79	-0.65	-0.32
QUIRCH	78.79	-	-	-0.75	-0.79
Brands (Promo)					
CTL	34.94	0.81	0.88	-0.91	-0.76
WESTERN	81.16	0.20	0.48	0.0006	-0.01
FRISCO	57.58	0.67	0.82	-0.87	-0.61
SEA	75.85	0.28	0.68	-1.96	-1.54
HN	89.39	0.25	0.55	-0.03	-0.01
RED	87.88	0.22	0.62	-0.13	-0.11
SWANDER	82.20	0.42	0.72	-0.55	-0.41
COLORADO	74.15	0.29	0.59	-0.77	-0.64
FISHIN	64.30	0.56	0.83	-0.49	-0.31
QUIRCH	78.79	-	-	-1.27	-1.01

Figure 1. Total Sales Trend of Shrimp, Salmon, and Tilapia Products Sold at Stores from 2009 to 2012

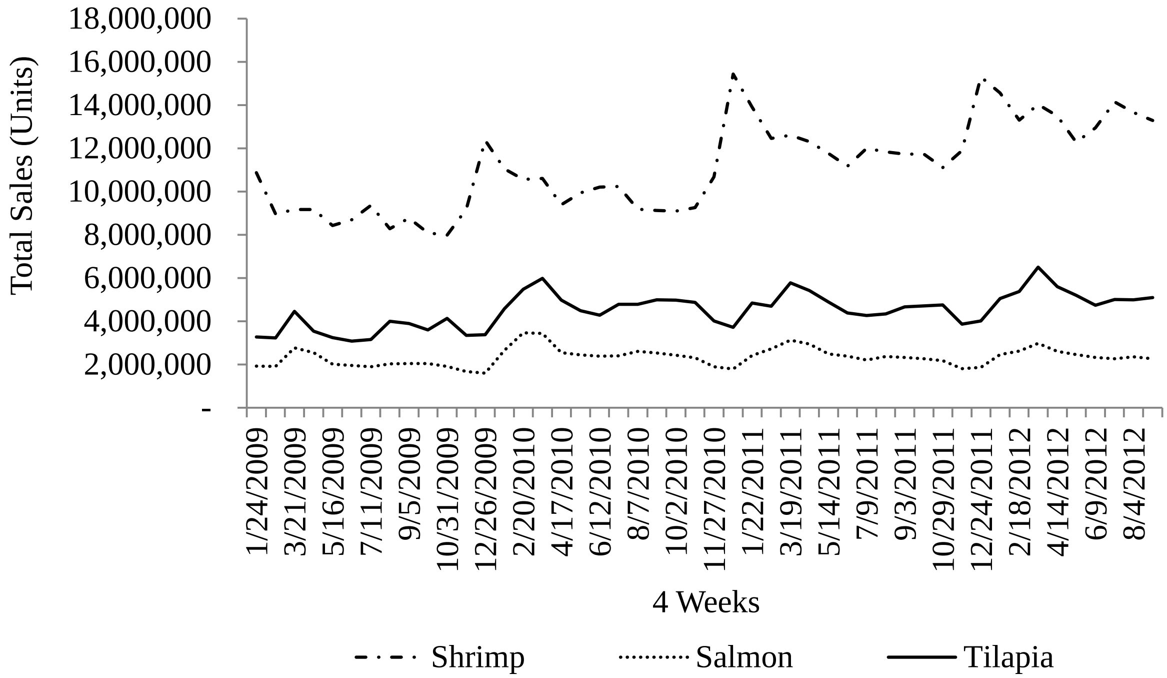

Figure 2. Total Prices of Shrimp, Salmon, and Tilapia Products from 2009 to 2012