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An Empirical Analysis of Factors Influencing Households' Demand for Omega-3 Enriched Eggs in the United States

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A Tobit model is estimated using the 2016 Nielsen Homescan panel data on household purchases to analyze the impact of socioeconomic variables on the demand for omega-3 eggs in the United States. Own price, price of conventional eggs, household income, and a set of household demographic characteristics emerge as statistically significant determinants of the quantity purchased of omega-3 eggs. The demand for omega-3 eggs is found to be elastic, conventional eggs are substitutes for omega-3 eggs, and omega-3 eggs are a normal good and a necessity.

Key words: Censored Demand, Nielsen Homescan Data, Omega-3 Eggs, Tobit Model

Appropriate healthy diets and food rich in health benefits are considered to be an integral part of a healthy lifestyle for consumers. In their diets, consumers regard food as an effective means for reducing risk of many diseases and for staying mentally and physically fit. The fast development of the food industry has been possible by using up-to-date technologies that would provide consumers with a large variety of food product categories possessing different beneficial nutrients. One of the notable developments in the food industry is related to the introduction of functional foods.

According to the American Dietetic Association (2009), functional foods are those that include whole foods and fortified, enriched, or enhanced foods that have a potentially beneficial impact on health when consumed regularly and at effective levels as part of a varied diet. Some functional foods are enriched with nutrients and vitamins to have health benefits. For instance, oatmeal is a functional food due to its content of soluble fiber that can help lower cholesterol levels, or, as a functional food, orange juice can be enriched with calcium to enhance bone health. Also, many products such as milk, eggs, yogurt, and peanut butter can be enhanced with beneficial omega-3 fatty acids to be classified as functional foods. The three important omega-3 fatty acids include alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA), with ALA being present primarily in plant oils (flaxseed, soybean, and canola), while DHA and EPA can be found in fish and other seafoods (U.S. Department of Health and Human Services, 2015). According to a Mintel report (2008), enriched eggs are one of the demanded foods in the list of omega-3 fortified products. Omega-3 enriched eggs come from hens whose

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feed is supplemented with an omega-3 source like flax seeds and they are higher in omega-3s than conventional eggs (Imran et al., 2015).

The demand for eggs has increased in the United States over the past few years with the per capita consumption reaching 277 eggs in 2017 (U.S. Department of Agriculture, 2019). At the same time, due to many health attributes associated with omega-3 products, the market for them has been on the rise as well. In 2018, the global omega-3 market was estimated at $2.29 billion and is projected to expand at a compound annual growth rate of 7.4% from 2019 to 2025 (Grand View Research, 2019). Per the Mintel report (2008), approximately 47% of respondents who bought omega-3 products said they regularly purchased omega-3 capsules or pills. Also, about 46% of these respondents said they regularly purchased omega-3 enriched eggs. Other popularly purchased omega-3 food products included cereal (40%), milk (39%), yogurt (38%), and oily fish (37%).

Omega-3 enriched eggs are an excellent and affordable source of various important nutrients for healthy diets of nutritionally vulnerable segments of the population facing limited food budgets. At the same time, growing consumer awareness of health attributes has positively contributed to the demand for omega-3 enriched eggs. However, many stores, along with omega-3 enriched eggs, also offer conventional eggs, thereby contributing to a rather competitive retail landscape in the egg market. As such, research is needed to better understand patterns of omega-3 enriched egg consumption across diverse demographic groups that would provide information for the sake of better positioning of omega-3 eggs relative to a competitor (for example, conventional eggs) and would result in recommendations geared toward the improvement of the nutrient adequacy of these demographic groups. This study provides that information by conducting a household-level demand analysis of omega-3 enriched eggs in the United States.

The overall purpose of this analysis is to provide insights into the determinants of the U.S. households' demand for omega-3 enriched eggs. More specifically, the objectives of this analysis are to: (1) compute the market penetration for omega-3 enriched eggs; (2) determine unconditional and conditional economic factors (such as prices) and household demographic characteristics that impact the quantity purchased of omega-3 enriched eggs; (3) compute unconditional and conditional own-price, cross-price, and income elasticity of demand for omega-3 enriched eggs; and (4) calculate the changes in the probability of purchasing omega-3 enriched eggs resulting from a change in a household demographic characteristic for omega-3 enriched egg consuming households.

The empirical findings from this study are expected to enhance our understanding of household demand behavior with respect to omega-3 enriched eggs in the United States and, at the same time, can be of significance to different stakeholders. In particular, they can help omega-3 enriched egg manufacturers and distributors in designing corresponding pricing and promotional strategies in order to maximize sales revenues, in generating demand forecasts to assist in input procurement and inventory management, and in developing marketing strategies geared towards specific demographic groups outside of their traditional consumer base. Additionally, the findings from this study can help egg manufacturers gain insight into drivers of household consumption behavior and their implications for omega-3 enriched eggs, which is information that can be used in developing new products geared towards current and new customer base. Furthermore, the findings from this study can shed light on price differences associated with omega-3 enriched eggs and conventional eggs, providing beneficial information to stores selling differentiated eggs in facilitating pricing decisions. In addition, policy-makers can use the empirical results from this study to identify potential economic and demographic barriers to increasing omega-3 enriched egg consumption and formulate corresponding policies to overcome these barriers for nutritionally vulnerable demographic groups. Finally, the empirical findings from this study can benefit domestic egg producers in their production decisions and policy-makers in their effort to formulate programs directed at boosting the U.S. egg industry.

The rest of the paper proceeds as follows. The next section deals with the literature review, which is followed by the presentation and discussion of the Tobit model. Then, the empirical specification of the Tobit model and the estimation procedure are discussed. The data used in this study are presented and discussed in the following section. The subsequent section provides the discussion of the empirical results from the Tobit model estimation. Concluding remarks and recommendations for future research are outlined in the final section.

Literature Review

Previous research has been helpful in providing insights into the demand for omega-3 enriched eggs and contributing to our understanding of the drivers that affect their consumption. In particular, to assess the effects of Canadian consumers' health consciousness, health behavior, their attitudes towards the issues concerning animal welfare, environmental impacts, reading labels, and engineered foods, and demographic characteristics (gender, age, number of minors in the household) on their willingness to pay for omega-3 and vitamin-enriched eggs, Asselin (2005) estimated a conditional logit model using data from the stated preference survey conducted in March 2005. The estimation results indicated that consumers' health consciousness and health behavior were positively associated with their willingness to pay for the functional attributes present in omega-3 enriched eggs. In addition, the price and the perception of benefits from consuming engineered foods were found to be negatively associated with the utility gained from the consumption of omega-3 enriched eggs. The impact of demographic characteristics was statistically insignificant.

In their study, Chase et al. (2009) analyzed the effects of household demographic variables (household head's age and education, household's region of residence, income, and presence of children in the household), awareness of the Nutrition Facts table and Canada's Food Guide, and consideration of health benefits on the purchases of omega-3 enriched eggs, milk, yogurt, and margarine in Canada. The ordered probit model was estimated for each omega-3 enriched product using Nielsen Homescan data from March 2005 to March 2006. The dataset was also supplemented with the information regarding households' knowledge of the Nutrition Facts table and Canada's Food Guide, as well as consideration of health benefits when buying foods from a survey involving the same Nielsen participant households for a total of 7,947 observations. According to the empirical results, the residence region emerged as a significant driver of omega-3 enriched egg purchases, with the households from most of the Canadian regions being more likely to frequently purchase omega-3 enriched eggs. Higher-income households and households with heads with progressively higher levels of education were more likely to frequently purchase omega-3 enriched eggs. Households with heads aged 65 and older were more likely to purchase omega-3 enriched eggs, compared to households with heads of any other age category. Households with children were more likely to never purchase omega-3 enriched eggs, compared to households without children. Reading the Nutrition Facts table positively affected the likelihood of households frequently purchasing omega-3 enriched eggs. Finally, consideration of health benefits when buying food was found to be positively associated with the probability of frequently purchasing omega-3 enriched eggs.

By estimating a logit model and applying household-level data derived from Nielsen Homescan panels ranging from 1998 through 2007 and containing 1,565,320 observations, Shiratori (2011) analyzed the impacts of a set of household demographic characteristics on the likelihood of purchasing omega-3 enriched eggs in the United States. As well, the logit model was augmented to incorporate media indices related to the health and developmental benefits of increasing the use of omega-3 fatty acids in human diets. According to the estimation results, household size negatively impacted the probability of purchasing omega-3 enriched eggs. Household income was a key factor positively impacting the probability of purchasing omega-3 enriched eggs. Likewise, the age of the household head was found to be positively associated with the probability of purchasing omega-3 enriched eggs. Households that had heads with a college degree had a higher probability of purchasing omega-3 enriched eggs. Households residing in urban areas were more likely to purchase omega-3 enriched eggs. Relative to households residing in the South, households from the East were more likely and the households from the Central and Western regions were less likely to purchase omega-3 enriched eggs. Seasonal dummies suggested that the probability of purchasing omega-3 enriched eggs was higher in spring and fall than in summer. The price of regular eggs positively impacted the probability of purchasing omega-3 enriched eggs, while the coefficient associated with the own price of omega-3 enriched eggs was not statistically significant. Having a discounted sale deal for regular eggs decreased the probability of purchasing omega-3 enriched eggs. Finally, both media indices concerning the health and developmental benefits of increasing the use of omega-3 fatty acids in human diets were positively associated with the probability of purchasing omega-3 enriched eggs.

Heng (2015) analyzed the demand for conventional and specialty eggs by estimating a Berry, Levinsohn and Pakes random coefficient logit model and using household-level data from Nielsen spanning from April 2008 to March 2010. Egg products were defined based on combinations of product characteristics including egg manufacturer brand, shell color, organic production, and health benefits associated with omega-3 and vitamins (i.e., nutrient-enhanced). The estimation results showed that the own-price elasticity of the private-label nutrient-enhanced eggs was -2.221, while that of the various brand-name nutrient-enhanced eggs ranged from -3.090 to -4.318, indicative of elastic demand for specialty eggs. Also, the calculated cross-price elasticities among brand-name nutrient-enhanced eggs ranged from 0.001 to 0.054, suggestive of substitutability relationship among specialty eggs.

Given the findings from prior studies, the present analysis makes several contributions to the literature. First, unlike prior studies, the present analysis focuses solely on the household-level demand for omega-3 enriched eggs in the United States, while directly accounting for censoring present in the data. Second, the present analysis furnishes two sets of marginal effects and corresponding demand elasticities, with one set pertaining to all the households regardless of the fact if they purchased omega-3 enriched eggs or not, and the other set concerning only the households that purchased omega-3 enriched eggs. Third, the present analysis additionally provides information on the change in the probability of being above zero-consumption level in response to a change in household demographic variables. Fourth, the model that the present analysis estimates is extended by including a few household demographic variables that were not considered in previous research.

The Tobit Model

When using household-level data, researchers usually have to deal with situations wherein households have zero consumption levels of products over the time period under study. A similar issue is encountered in Nielsen's Homescan panel data for household purchases employed in the present analysis when they reported no purchases of omega-3 enriched eggs spending zero dollars on them. Applying the ordinary least squares method to the sub-sample that contains only non-zero purchases without allowing for zero purchases leads to sample selection bias (Heckman, 1979) and inconsistent parameter estimates (Wooldridge, 2002). To circumvent this problem, a Tobit model (also called a censored regression model) is used in the present study where the explained variable is censored from below with the lower limit being zero purchases of omega-3 enriched eggs. The following discussion on the Tobit model is borrowed from McDonald and Moffitt (1980).

The stochastic model that the Tobit model is based upon is given as follows:

(1) $$y_i = \begin{cases} \mathbf{X}_i\beta + u_i, if\ \mathbf{X}_i\beta + u_i > 0 \\ 0\ if\ \mathbf{X}_i\beta + u_i \leq 0, i = 1,2, \ldots, N \end{cases},$$

where $i = 1,2,\ldots,N$ represents the number of observations, y_i is the regressand, $\mathbf{X}_i$ is a vector of regressors, β is a vector of conformable unknown parameters, and u_i is an independently distributed disturbance term following normal distribution with zero mean and constant variance. Leaving out the individual subscripts for notational convenience, the unconditional expected value of y_i, $E(y)$, is given by

(2) $$E(y) = \mathbf{X}\beta F(z) + \sigma f(z) \text{ and}$$

and the conditional expected value of y_i, $E(y^*)$ is as follows:

(3) $$E(y^*) = \mathbf{X}\beta + \sigma f(z)/F(z),$$

where the normalized index value $z = \mathbf{X}\beta/\sigma$, $f(z)$ is the unit normal density and F(z) is the cumulative distribution function. The unconditional marginal effect measuring the overall impact of a change in an independent variable on the dependent variable is defined as follows:

(4) $$\frac{\partial E(y)}{\partial \mathbf{X}} = \beta F(z).$$

The conditional marginal effect measuring the impact of a change in an independent variable on the dependent variable for $y_i > 0$ is defined as follows:

$$(5) \qquad \frac{\partial E(y^*)}{\partial \mathrm{x}} = \beta\left(1 - z\frac{f(z)}{F(z)} - \frac{f(z)^2}{F(z)^2}\right).$$

McDonald and Moffitt's (1980) decomposition linking changes in the conditional and unconditional expectations to each other is given by the following:

$$(6) \qquad \frac{\partial E(y)}{\partial \mathrm{x}} = F(z)\left(\frac{\partial E(y^*)}{\partial \mathrm{x}}\right) + E(y^*)\left(\frac{\partial F(z)}{\partial \mathrm{x}}\right).$$

Thus, the total change in y can be partitioned into two parts: (1) the change in y of those above the limit, weighted by the probability of being above the limit, and (2) the change in the probability of being above the limit, weighted by the expected value of y if above the limit.

Empirical Specification and Estimation Procedure

In this study, the quantity purchased of omega-3 enriched eggs is hypothesized to be affected by the own price, the price of conventional eggs, and a set of household demographic characteristics. Mathematically, the empirical specification of the Tobit model reflecting this relationship has the following form:

$$(7) \qquad Q_{omega3i} = \alpha_0 + \alpha_1 P_{omega3i} + \alpha_2 P_{convi} + \alpha_3 I_i + \alpha_4 \mathbf{Z}_i + \varepsilon_i,$$

where $i = 1,2,\ldots,N$ is the number of observations, $Q_{omega3i}$ is the quantity purchased of omega-3 enriched eggs, $P_{omega3i}$ is the price of omega-3 enriched eggs, P_{convi} is the price of conventional eggs, I_i is household income, $\mathbf{Z}_i$ is a vector of household demographic characteristics, αs are unknown parameters to be estimated, and ε_i is the error term.

Table 1 shows the description of the variables used in this analysis along with indicating the corresponding base categories for each group of demographic variables. Household demographic characteristics pertain to size, presence of children, age, employment status, education level, marital status, race, and ethnicity of the household head. All the household demographic characteristics are operationalized and included in the model as dummy variables. In the Nielsen Homescan panel data, household income is reported in brackets and is expressed in thousand dollars. The household income variable is operationalized by recording the median point for a bracket to reflect the actual income for a particular household. For example, a bracket of \$5,000-\$7,999 has a value of \$6,500 recorded as an actual household income.

In the Nielsen Homescan panel data, prices are not reported. As such, unit values (henceforth prices) found by dividing reported total dollar sales (expenditures) by reported volume sold are used as proxies for prices of omega-3 enriched eggs and conventional eggs. For households that reported zero purchases of omega-3 enriched eggs or conventional eggs and, hence zero expenditures, the corresponding prices had to be imputed. This imputation was accomplished by regressing actual prices of omega-3 enriched eggs and conventional eggs on household income, household size, and the region in which the household resided, as suggested by prior studies (Kyureghian, Capps, and Nayga, 2011; Alviola and Capps, 2010; Dharmasena and Capps, 2014). The household income captures various levels of product quality as it is reflected by the price of the product, household size captures the differences in socio-economic and demographic conditions and their influence on price, and household region accounts for the spatial variation in price. The predicted values for both prices were generated using the estimated regression models to complete the price imputation process for both omega-3 enriched egg price and conventional egg price.

Another issue with prices relates to the endogeneity in prices, since the latter account for not only the market price variations, but also quality variations which are affected by the composition of household purchases over the individual products (Deaton, 1988; Dong, Shonkwiler, and Capps, 1998; Dong and Kaiser, 2005). Following previous studies (Alviola and Capps, 2010; Dharmasena and Capps, 2014), the endogeneity issue present in the prices was addressed by using the predicted values for both prices generated during the imputation process above because those predicted values were generated based on the household income, size, and region used as instruments. As a result of the price imputation, the issues related to missing prices and endogeneity were handled.

Finally, the empirical Tobit model with the natural logarithmic form of prices and income (semi-log model) was run given its superiority to the model with linear prices and income associated with the efficiency and significance of parameter estimates. For the discussion of marginal effects and elasticities, we follow Dharmasena and Capps (2014). The unconditional marginal effect associated with the price variable (both the price of omega-3 enriched eggs and the price of conventional eggs) in the semi-log model is as follows

$$\frac{\partial E(y)}{\partial p} = \frac{\alpha F(z)}{p^u}, \tag{8}$$

where p^u is the unconditional mean price computed using all observations (unconditional sample). The conditional marginal effect associated with the price variable (both the price of omega-3 enriched eggs and the price of conventional eggs) in the semi-log model looks as follows:

$$(9) \qquad \frac{\partial E(y^*)}{\partial p} = \frac{\alpha}{p^c}\left(1 - z\frac{f(z)}{F(z)} - \frac{f(z)^2}{F(z)^2}\right),$$

where p^c is the conditional mean price computed using the conditional sample (censored sample). The unconditional marginal effect associated with the household income variable in the semi-log model is given by

$$(10) \qquad \frac{\partial E(y)}{\partial I} = \frac{\alpha_3 F(z)}{I^u},$$

where I^u is the unconditional mean household income computed using all observations (unconditional sample). The conditional marginal effect associated with the household income variable in the semi-log model is

$$(11) \qquad \frac{\partial E(y^*)}{\partial I} = \frac{\alpha_3}{I^c}\left(1 - z\frac{f(z)}{F(z)} - \frac{f(z)^2}{F(z)^2}\right),$$

where I^c is the conditional mean household income computed using the conditional sample (censored sample). Unconditional and conditional own-price, cross-price, and income elasticities of demand for omega-3 enriched eggs are calculated using the corresponding marginal effects. In particular, unconditional own-price elasticity of demand for omega-3 enriched eggs (e^u_{omega3}), cross-price elasticity of demand for omega-3 enriched eggs with respect to the price of conventional eggs ($e^u_{Qomega3\_Pconv}$), and income elasticity of demand for omega-3 enriched eggs (e^u_I) calculated at the sample means are as follows, respectively,

$$(12) \qquad e^u_{omega3} = \frac{\alpha_1 F(z)}{P^u_{omega3}} \frac{P^u_{omega3}}{Q_{omega3}{}^u} = \frac{\alpha_1 F(z)}{Q_{omega3}{}^u},$$

$$(13) \qquad e^u_{Qomega3\_Pconv} = \frac{\alpha_2 F(z)}{P^u_{conv}} \frac{P^u_{conv}}{Q_{omega3}{}^u} = \frac{\alpha_2 F(z)}{Q_{omega3}{}^u},$$

and

(14) $$e_I^u = \frac{\alpha_3 F(z)}{I^u}\frac{I^u}{Q_{omega3}{}^u} = \frac{\alpha_3 F(z)}{Q_{omega3}{}^u}.$$

Conditional own-price elasticity of demand for omega-3 enriched eggs (e^c_{omega3}), cross-price elasticity of demand for omega-3 enriched eggs with respect to the price of conventional eggs ($e^c_{Qomega3\_Pconv}$), and income elasticity of demand for omega-3 enriched eggs (e^c_I) calculated at the sample means look as follows, respectively,

(15) $$e^c_{omega3} = \frac{\alpha_1}{P^c_{omega3}}\left(1 - z\frac{f(z)}{F(z)} - \frac{f(z)^2}{F(z)^2}\right)\frac{P^c_{omega3}}{Q_{omega3}{}^c} = \frac{\alpha_1}{Q_{omega3}{}^c}\left(1 - z\frac{f(z)}{F(z)} - \frac{f(z)^2}{F(z)^2}\right),$$

(16) $$e^c_{Qomega3\_Pconv} = \frac{\alpha_2}{P^c_{conv}}\left(1 - z\frac{f(z)}{F(z)} - \frac{f(z)^2}{F(z)^2}\right)\frac{P^c_{conv}}{Q_{omega3}{}^c} = \frac{\alpha_2}{Q_{omega3}{}^c}\left(1 - z\frac{f(z)}{F(z)} - \frac{f(z)^2}{F(z)^2}\right),$$

and

(17) $$e^c_I = \frac{\alpha_3}{I^c}\left(1 - z\frac{f(z)}{F(z)} - \frac{f(z)^2}{F(z)^2}\right)\frac{I^c}{Q_{omega3}{}^c} = \frac{\alpha_3}{Q_{omega3}{}^c}\left(1 - z\frac{f(z)}{F(z)} - \frac{f(z)^2}{F(z)^2}\right).$$

Finally, from equation (6), changes in the probability of being above the limit for purchasing omega-3 enriched eggs resulting from a change in an independent variable ($\frac{\partial F(z)}{\partial X}$) can be obtained as follows:

(18) $$\frac{\partial F(z)}{\partial X} = \frac{1}{E(y^*)}\left(\frac{\partial E(y)}{\partial X}\right) - F(z)\left(\frac{\partial E(y^*)}{\partial X}\right).$$

Data

The data for the present analysis are obtained from the Nielsen Homescan panel for calendar year 2016[1], which contains information on 63,150 households in the United States. Nielsen Homescan panels are the largest on-going household scanner data survey system, tracking purchases made by households. Nielsen Homescan panel data consist of daily retail food purchases for at-home use along with household demographic characteristics (age, education level, employment status, and marital status of household

[1] The conclusions drawn from the Nielsen data are those of the researcher(s) and do not reflect the views of Nielsen. Nielsen is not responsible for, had no role in, and was not involved in analyzing and preparing the results reported herein.

heads, household size, presence of children in the household, household income, etc.). Every participating household is given a handheld scanner to scan universal product codes of all purchased products after each shopping trip to upload the purchase records (product description and characteristics, quantity purchased, expenditure, and promotion information) to Nielsen.

For the present analysis, household-level cross-sectional data ranging from January 1 through December 27, 2016, and pertaining to omega-3 enriched eggs are used, serving as a baseline study in the consideration of household demand for omega-3 enriched eggs. Omega-3 enriched eggs were disentangled from other types of eggs using the universal product code description. For each cross-sectional unit (i.e., household), purchases of omega-3 enriched eggs are aggregated. The household demographic characteristics used in the demand estimation for omega-3 enriched eggs are related to household size, presence of children in the household, household head's age, employment status, education level, marital status, race, and ethnicity. Operating under the assumption that the female head is mainly responsible for decision-making concerning grocery purchases, a female head is considered the household head. In the absence of a female head in the household, a male is considered the household head.

Descriptive statistics of the variables used in this analysis are shown in Table 1. In Table 1, the information regarding economic variables such as price and quantity of omega-3 enriched eggs and conventional eggs is given for both the unconditional sample and conditional sample. The unconditional sample reflects information for all the households included in the analysis (whether they purchased omega-3 eggs or not) and consists of 63,150 observations. The conditional sample contains information regarding those households that purchased omega-3 enriched eggs at least once during calendar year 2016 and consists of 12,712 observations. As such, the market penetration for omega-3 enriched eggs is 20.13%.

The price variable used in the estimation of the Tobit model is computed by dividing total expenditure by the quantity purchased of eggs and is expressed in dollars per count, while the quantity variable is expressed in counts (i.e., the measurement unit is one egg). The unconditional mean price of omega-3 enriched eggs and conventional eggs is $0.2/count and $0.134/count, respectively, suggesting that omega-3 enriched eggs on average are more expensive than conventional eggs. The unconditional average quantity purchased of omega-3 enriched eggs is 45.910. The conditional average price of omega-3 enriched eggs is $0.198/count and $0.135/count for conventional eggs, indicating that omega-3 enriched eggs are higher-priced relative to conventional eggs. The conditional average quantity purchased of omega-3 eggs is 228.071 and the average household income is $59,608.

Table 1. Description and Descriptive Statistics of the Variables Used in the Analysis.

Variable	Units of Measurement	Mean	Standard Deviation
Unconditional price of omega-3 eggs	dollars per count	0.20	0.019
Unconditional price of conventional eggs	dollars per count	0.134	0.016
Unconditional quantity of omega-3 eggs	count	45.910	127.435
Conditional price of omega-3 eggs	dollars per count	0.198	0.017
Conditional price of conventional eggs	dollars per count	0.135	0.014
Conditional quantity of omega-3 eggs	count	228.071	197.817
Household income	thousand dollars	59.608	29.340
Household size: one member		0.246	0.430
Household size: two members		0.409	0.492
Household size: three members		0.144	0.351
Household size: four members		0.121	0.326
Household size: five members and more*		0.080	0.271
Presence of at least one child below 18 years		0.239	0.427
Presence of no children below 18 years*		0.761	0.427
Age of the household head less than 25 years		0.006	0.078
Age of the household head between 25-44 years		0.244	0.430
Age of the household head between 45-64 years		0.505	0.500
Age of the household head 65 years and greater*		0.245	0.430
Employment status: employed, working hours less than 35 hours/week		0.180	0.384
Employment status: employed, working hours more than 35 hours/week		0.393	0.488
Employment status: unemployed*		0.427	0.495
Education level: less than high school degree		0.019	0.138
Education level: high school only		0.238	0.426
Education level: some college degree only		0.297	0.457
Education level: at least college degree*		0.445	0.497
Marital status: married		0.646	0.478
Marital status: widowed		0.071	0.258
Marital status: divorced or separated		0.144	0.351
Marital status: single*		0.138	0.345
Race: White		0.812	0.391
Race: Black		0.106	0.308
Race: Asian		0.034	0.182
Race: other (non-Black, non-White, non-Asian)*		0.047	0.212
Hispanic ethnicity		0.066	0.249
Non-Hispanic ethnicity*		0.934	0.249
Region: East		0.380	0.485
Region: Central		0.425	0.494
Region: West*		0.195	0.396

Notes. a. For the unconditional and demographic variables the sample size is 63,150, while for the conditional variables the sample size is 12,712. b. Asterisk indicates the base category. c. Researcher(s) own analyses calculated (or derived) based in part on 2016 Nielsen data from The Nielsen Company (US), LLC and marketing databases provided through the Nielsen Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business.

The household size measures the number of household members and is divided into five groups, ranging from one-member households to households with five and more members. Almost 41% of the sample households are those with two members. The characteristic of the age and presence of children less than 18 years old is classified into two groups: at least one child less than 18 years of age present in the household and no children in the household below 18 years of age. A little more than three-quarters of households (76.1%) report not having children of less than 18 years of age. The age of the household head characteristic is classified into four categories from "less than 25 years" to "65 years and greater". Slightly over half of the sample households (50.5%) have heads aged between 45 and 64 years. Employment status reflects whether household heads are employed for less than 35 hours per week, for more than 35 hours per week, or are unemployed. About 43% of the sample households have heads that are unemployed.

Education level represents the level attained by the household heads and is divided into four categories: less than high school degree, high school degree only, some college only, and at least college degree. About 45% of the sample households have heads with at least a college degree. Marital status of household heads is divided into four categories: married, widowed, divorced or separated, and single. Married household heads account for a little less than two-thirds of the sample (64.6%). Race of the household head is classified as White, Black, Asian, and other. White household heads account for 81.2% of the sample. Household ethnicity is classified as Hispanic origin or not Hispanic origin. The vast majority of households (93.4%) report heads of non-Hispanic origin.

Empirical Results

The parameter estimates and their standard errors from the Tobit regression for omega-3 enriched eggs obtained using the PROC QLIM procedure of the Statistical Analysis Software (SAS) version 9.4 are shown in Table 2. These Tobit parameter estimates do not provide direct intuitive economic interpretation. However, they indicate statistically significant determinants of the quantity purchased of omega-3 enriched eggs and are also used in the computation of more meaningful marginal effects and demand elasticities.

As the estimation results in Table 2 show, the statistically significant determinants of the quantity purchased of omega-3 enriched eggs include own price, price of conventional eggs, household income, household size, age of the household head, and household head's employment status, education level, marital status, and ethnicity. The corresponding mean unconditional and conditional marginal effects, as well as the mean change in the probability of being above the limit for change in every demographic variable for omega-3 enriched eggs, are also presented in Table 2. While Table 2 reports these estimation results at the three conventional significance levels (1%, 5%, and 10%), the actual interpretation and discussion of all marginal effects and the change in the probability are done based on the 5% significance level and one at a time, holding the effects of other variables constant.

The R-square statistic is computed by squaring the correlation between the predicted and observed values of quantity purchased of omega-3 enriched eggs. It is equal to 0.032, meaning that predicted values share 3.2% of their variance with the dependent variable. Per the estimation results in Table 2, even though the mean unconditional marginal effects are lower in value compared to the mean conditional marginal effects, however, both marginal effects are similar in terms of their signs, except for the education level of having only a high school education.

Table 2. Tobit Regression Results, Mean of Unconditional and Conditional Marginal Effects, and Mean Change in the Probability of Being above the Limit for Change in every Demographic Variable for Omega-3 Eggs.

Variable	Estimate	Standard Error	Mean Unconditional Marginal Effects	Mean Conditional Marginal Effects	Mean Change in the Probability
Log price of omega-3 eggs (dollars per count)	-2661.206***	66.912	-532.526***	-622.373***	
Log price of conventional eggs (dollars per count)	1578.650***	46.293	315.899***	369.197***	
Log of household income (thousand dollars)	204.182***	5.561	40.858***	47.752***	
Household size: one member	341.091***	16.337	68.255***	79.771***	0.253***
Household size: two members	250.983***	12.424	50.223***	58.697***	0.186***
Household size: three members	199.077***	11.230	39.837***	46.558***	0.148***
Household size: four members	174.498***	10.800	34.918***	40.810***	0.130***
Presence of at least one child below 18 years	11.448	8.589	2.291	2.677	0.009
Age of the household head less than 25 years	-25.320	30.217	-5.067	-5.922	-0.019
Age of the household head between 25-44 years	-25.284***	8.107	-5.060***	-5.913***	-0.019***
Age of the household head between 45-64 years	-32.836***	6.174	-6.571***	-7.679***	-0.024***
Employment status: employed, working hours less than 35 hours/week	-9.255	6.410	-1.852	-2.164	-0.007
Employment status: employed, working hours more than 35 hours/week	-39.279***	5.697	-7.860***	-9.186***	-0.029***
Education level: less than high school degree	-41.249**	17.476	-8.254**	-9.647**	-0.031**
Education level: high school only	-49.477***	6.102	9.901***	-11.571***	0.060***
Education level: some college degree only	-8.934*	5.336	-1.788*	-2.089*	-0.007*
Marital status: married	27.705***	9.022	5.544***	6.479***	0.021***
Marital status: widowed	16.408	11.141	3.283	3.837	0.012
Marital status: divorced or separated	19.839**	8.854	3.970**	4.640**	0.015**
Race: White	-17.376	11.127	-3.477	-4.064	-0.013
Race: Black	-3.949	12.761	-0.790	-0.924	-0.003
Race: Asian	-0.110	15.969	-0.022	-0.026	-0.0001
Hispanic ethnicity	49.532***	9.373	9.912***	11.584***	0.037***
Intercept	-2469.110***	77.704			
Sigma	397.485***	2.940			
Log Likelihood	-111922				
R-square	0.032				

*Notes: a. * = .10 level (10%), ** = .05 level (5%), *** = .01 level (1%). b. Number of observations for unconditional estimates is 63,150, while that of conditionals is 12,712. c. Researcher(s) own analyses calculated (or derived) based in part on data from The Nielsen Company (US), LLC and marketing databases provided through the Nielsen Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business. d. The R-square statistic was calculated as a squared correlation coefficient between the actual and predicted values of the dependent variable*

As such, the discussion of the results in Table 2 is done in terms of the mean conditional marginal effects and the corresponding mean change in the probability of being above the limit for change in a demographic variable for omega-3 enriched eggs. Household size emerges as an important factor impacting the quantity purchased of omega-3 enriched eggs. Compared to household size equal to or greater than five members, one-member, two-member, three-member, and four-member households are on average 13%-25% more likely to purchase omega-3 enriched eggs and, on average, buy 41-80 more eggs. Age of household heads is a key factor in purchasing omega-3 enriched eggs. Households that have heads who are between 25 and 44 years old and between 45 and 64 years old are, on average, 1.9% and 2.4%, respectively, less likely to purchase omega-3 enriched eggs and buy, on average, about six and eight eggs less, respectively, relative to households headed by a person aged 65 and above.

Households that have employed heads working more than 35 hours per week on average purchase about nine omega-3 enriched eggs less with an average probability of 3%, compared to households that have unemployed heads. Household heads' education level plays an important role significantly affecting purchases of omega-3 enriched eggs. In particular, compared to households that have heads with at least a college degree, households that have heads with less than a high school degree are, on average, 3% less likely to purchase omega-3 enriched eggs and buy, on average, about 10 eggs less. High school-educated household heads are, on average, 6% more likely to buy omega-3 enriched eggs and purchase on average about 12 eggs less, relative to households that have heads with at least a college degree.

Marital status also is an important factor impacting households' purchases of omega-3 enriched eggs. The probability of purchasing omega-3 enriched eggs, on average, increases by about 2% for households that have married heads and they purchase, on average, six more eggs in comparison to the reference group of households that have single heads. In addition, households with divorced or separated heads, on average, purchase about five omega-3 enriched eggs more than the households with single heads with an average 1.5% greater probability. Finally, households with Hispanic heads, on average, purchase about 12 more omega-3 enriched eggs than households headed by a non-Hispanic head with an average of 3.7% greater probability. It needs to be noted that these empirical findings are consistent with the results obtained in the studies by Chase et al. (2009) and Shiratori (2011).

The mean of unconditional and conditional own-price, cross-price, and income elasticities of demand for omega-3 enriched eggs calculated at the sample means and using the corresponding parameter estimates from the Tobit model are presented in Table 3. Across the three demand elasticities, absolute values of unconditional elasticities are slightly less than their conditional counterparts. The means of the unconditional and conditional own-price elasticity of demand for omega-3 enriched eggs are negative, in accordance with the law of demand, and are equal to -2.335 and -2.729, respectively. These own-price elasticities of demand suggest that for a 1% increase in the price of omega-3 enriched eggs, on average the mean unconditional and conditional quantity purchased of omega-3 enriched eggs goes down by 2.335% and 2.729%, respectively, everything else held constant. Additionally, both values of the own-price elasticities imply that the demand for omega-3 enriched eggs is elastic, necessitating a decrease in own price for the sake of raising sales revenues in the short-run for omega-3 enriched eggs manufacturers. These results are consistent with a prior study by Heng (2015), who estimated the own-price elasticity of the private-label nutrient-enhanced eggs (omega-3 and vitamin enriched) to be -2.221, while that of the various brand-name nutrient-enhanced eggs went from -3.090 to -4.318, revealing an elastic demand for specialty eggs.

Table 3. Unconditional and Conditional Demand Elasticities from the Tobit Model and Demand Elasticities from Heckman's Two-Stage Procedure for Omega-3 Eggs.

Elasticity	Mean Unconditional (Tobit)	Mean Conditional (Tobit)	Heckman
Own-price elasticity of demand for omega-3 eggs	-2.335	-2.729	-3.633
Cross-price elasticity of demand for omega-3 eggs wrt to the price of conventional eggs	1.385	1.619	1.228
Income elasticity	0.179	0.209	0.015

Notes: a. Estimation results from Heckman's two-stage procedure are available upon request. b. Researcher(s) own analyses calculated (or derived) based in part on data from The Nielsen Company (US), LLC and marketing databases provided through the Nielsen Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business.

The mean of the unconditional cross-price elasticity of demand for omega-3 enriched eggs with respect to the price of conventional eggs is 1.385, meaning that, as anticipated, conventional eggs are a substitute product for omega-3 enriched eggs and that a 1% increase in the price of conventional eggs increases the mean unconditional quantity purchased of omega-3 enriched eggs by 1.385%, everything else held constant. As well, the mean of the conditional cross-price elasticity of demand for omega-3 enriched eggs with respect to the price of conventional eggs is 1.619, again, expectedly suggesting that conventional eggs are a substitute product for omega-3 enriched eggs and that for every 1% increase in the price of conventional eggs, the mean conditional quantity purchased of omega-3 enriched eggs goes up by 1.619%, everything else held constant. This finding is consistent with the one obtained by Heng (2015) who also found a substitutability relationship among specialty eggs.

The mean unconditional and conditional values of the income elasticity of demand for omega-3 enriched eggs are 0.179 and 0.209, respectively. These positive values demonstrate that omega-3 enriched eggs are a normal good and are a necessity. Also, for every 1% increase in household income, the mean unconditional and conditional quantity purchased of omega-3 enriched eggs increase by 0.179% and 0.209%, respectively, holding everything else constant. This finding is in agreement with prior studies that confirmed household income as a major contributor to the purchase of omega-3 enriched eggs (Chase et al., 2009; Shiratori, 2011).

For the purpose of comparison, Table 3 also shows the estimates of own-price, cross-price, and income elasticities of demand associated with omega-3 eggs obtained from the Heckman two-stage sample selection model. These estimates reveal no qualitative difference between them and the estimates of demand elasticities from the Tobit procedure. In particular, the estimate of the own-price elasticity of demand from Heckman's two-stage procedure (-3.633) indicate an elastic demand for omega-3 eggs. Also, the estimate of cross-price elasticity of demand for omega-3 eggs with respect to the price of conventional eggs (1.228) reveal a substitutability relationship between omega-3 and conventional eggs. Finally, the estimate of income elasticity of demand from Heckman' s two-stage procedure (0.015) suggests that households view omega-3 eggs as a normal good and a necessity. While both the Tobit and the Heckman procedures are designed to handle the issue of zero purchases (i.e., censoring in dataset), in the present analysis, the Tobit model was chosen because it provides more information relative to the Heckman procedure. First, the Tobit model yields two sets of marginal effects and elasticities, conditional and unconditional, as opposed to only conditional marginal effects and elasticities estimated by the Heckman two-stage procedure. Second, the change in the probability of being above the limit for change in an independent variable can be obtained from the Tobit model, with no such information estimated by the Heckman two-stage procedure.

Concluding Remarks and Recommendations for Future Research

This study estimates a Tobit model to investigate the impact of prices, household income, and household demographic characteristics on the quantity purchased of omega-3 enriched eggs, employing data developed from the Nielsen Homescan panel for calendar year 2016. The study computes the market penetration for omega-3 enriched eggs to be 20.13%. Also, according to the estimation results, the own price of omega-3 enriched eggs, the price of conventional eggs, household income, as well as a number of household demographic characteristics, emerge as significant factors influencing the quantity purchased of omega-3 enriched eggs, information that can be useful in formulating policies targeting vulnerable demographic groups in an attempt to improve their nutrient adequacies.

Per the own-price demand elasticity estimate, the demand for omega-3 enriched eggs can be classified as elastic, suggestive of consumer sensitivity to omega-3 enriched egg price changes. To take advantage of this fact, omega-3 enriched egg manufacturers are advised to lower their prices in order to maximize their short-run revenues from sales. At the same time, elastic demand for omega-3 enriched eggs implies that manufacturers of this type of eggs will be impacted by tax and will be unable to pass any cost increase onto consumers, to the extent that the demand is elastic.

According to the positive cross-price elasticity of demand for omega-3 enriched eggs with respect to the price of conventional eggs, conventional eggs are found to be substitutes for omega-3 enriched eggs. This result can be used by omega-3 enriched egg manufacturers and distributors to form demand forecasts to facilitate decisions associated with input procurement and inventory management in response to conventional egg price changes. Finally, the value of the income elasticity of demand for omega-3 enriched eggs imply that they are a normal good and a necessity, which is a significant piece of information for manufactures and policy-makers for predicting changes in household purchases of omega-3 enriched eggs for a given change in household income.

A few recommendations for future research are worth mentioning. First, future research would benefit by also considering factors associated with purchase channels (conventional supermarkets, supercenters, wholesale clubs, etc.), households' health status, and households' away-from home consumption of omega-3 enriched eggs. Second, it would be beneficial for future research to include the time dimension into analysis to capture the potential dynamics in the household buying behavior dealing with omega-3 enriched eggs. Third, it is recommended that future research replicate this study with more current data.

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