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Bayesian Estimation of a Censored AIDS Model for Whole Grain Products

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Abstract

When using household-level data in examining consumer's demand it is common to find that consumers purchase only a subset of the available goods, setting the demand for the remaining goods to zero. Ignoring such censoring of the dependent variables in the estimation can lead to biased parameter estimates. In this paper we investigate the household's demand for six types of whole grain and non-whole grain breakfast cereals and products using a censored Almost Ideal Demand System (AIDS) and estimate the parameters of the demand system via Bayesian methods. Using 2006 ACNielsen Homescan data we find that demand for whole grain and non-whole grain ready-to-eat cereals is less responsive to changes in prices; demand for whole-grain bars and non-whole grain hot cereals is relatively price sensitive. The elasticity estimates show that whole grain ready-to-eat cereals and whole grain bars have relatively higher expenditure elasticities than is the case for the other goods.

Key Words: AIDS model, Bayesian econometrics, censored, cereals, whole grains

JEL Classification: C11; C34; D12

Bayesian Estimation of a Censored AIDS Model for Whole Grain Products

The U.S. Department of Health and Human Services (USDHHS) and the U.S. Department of Agriculture (USDA) have publishing the *Dietary Guidelines for Americans* since 1980. The *Guidelines* provide dietary recommendations to guide the development of nutrition programs and to help and encourage consumers to choose diets that meet their nutritional needs and improve their health. The guidelines are revised every 5 years based on the findings from recent research. The 2005 *Guidelines* put new emphasis on whole grain consumption by recommending consumption of at least three servings of whole grains per day. Whole grains were defined as: "Whole grains, as well as foods made from them, consist of the entire grain seed, usually called the kernel. The kernel is made of three components - the bran, the germ and the endosperm. If the kernel has been cracked, crushed, or flaked, then it must retain nearly the same relative proportion of bran, germ, and endosperm as the original grain in order to be called whole grain" (US DHHS and USDA 2005). Consumption of diets high in whole grains have been reported to have a number of beneficial health effects including reduced risk of cancer (Jacobs, et al. 1998), cardiovascular disease (Truswell, 2002; Liu et al. 1999), diabetes (Fung et al. 2002; Liu et al. 2000), blood pressure (Hallfrisch et al. 2003) and cholesterol (Lumpton, et al. 1994).

The U.S. Food and Drug Administration (FDA) which regulates U.S. nutrition labeling of most foods and authorizes the use of nutrient and health claims has allowed three health claims related to grain intakes (FDA, 2008). A specific claim for whole grain foods allows the statement that diets rich in whole grain foods and other plant foods and low in total fat, saturated fat, and cholesterol may reduce the risk of heart disease and some cancers. The release of the 2005 *Dietary Guidelines* and FDA consideration of health related claims gave whole grain manufacturers the opportunity to differentiate their products from refined grain products and the incentive to produce more whole grain products or reformulate their products to meet the whole grain requirements. While FDA has no mandatory labeling requirements regarding whole grains, it recommends that manufacturers label whole grain content specifically (e.g., provides ½ ounce of whole grains). Other organizations such as the Whole Grains Council promote consumption of whole grains through a packaging symbol indicating whole grain content.

Although the lack of clear labeling makes it more difficult for consumers to identify whole-grain food products, the availability and consumption of whole grain products is likely to increase (Buzby, Farah and Volke 2005). And policymakers use recommendations from the 2005 *Dietary Guidelines* in the development of food program guidance. One example is the recently revised food packages for the Supplemental Nutrition Program Women, Infants and Children (WIC), which now include provisions to allow participants to buy whole grains products effective in 2009.

There are relatively few recent studies of grain consumption, although recent evidence from food intake surveys indicates that Americans consume less whole grain than recommended. Most whole grains come from crackers and snacks and from cereals (especially ready to eat cereals) (Mancino and Buzby 2005). Using data from 1994-96 and 1998 Lin and Yen (2007) compared grain consumption of individuals by economic and demographic characteristics and found that individuals consumed more than the recommended daily amount of all grain, while consuming only 34 percent of the amount of whole grain recommended by the 2005 *Dietary Guidelines*. Given the public health interest in increased consumption of whole grains, it is important to have a good understanding of basic demand parameters. In this paper, we consider demand for cereals and breakfast bars and major sources of whole grains in the diet. We use household level data and consider the issue of censoring in our estimation of a demand system for cereal and breakfast products.

When using household-level data in examining consumer's food demand it is common to find that consumers consume only a subset of the available goods, leaving observed demand for some of the goods to be zero. Ignoring such censoring of the dependent variable in the estimation can lead to biased parameter estimates. There exist a number of estimation procedures that handle this censoring problem (Wales and Woodland 1983; Lee and Pitt 1986). Although theoretically consistent these approaches suffer from the drawback that in the case of many non-consumed goods for some households, evaluation of multiple integrals is necessary. An alternative approach is an Amemiya-Tobin approach, which is the generalization of the Tobin's (1958) limited dependent variable model proposed by Amemiya (1974) and implemented by Wales and Woodland (1983). However, the use of Amemiya-Tobin type estimators are also complicated by the need for evaluating multiple integrals in cases where censoring is severe. Due to the complexity of estimating the models above, the two-step procedure based on the Amemiya-Tobin approach has been used to estimate censored demand systems (Shonkwiler and Yen (1999)). This method has been widely used in the applied literature. The advantage of the two-step procedure is its ability to estimate large systems, however two-step procedures are known to be inefficient and overlook the adding-up condition of the observed shares.

A number of papers used variations of the Amemiya-Tobin approach to deal with the issues of censoring (e.g.Yen and Roe (1989), Perali and Chavas (2000), Golan, Perloff and Shen (2001), Yen, Kan and Su (2002), Dong, Gould and Kaiser (2004) and Yen (2005)). However, a problem arises from the presence of truncated distributions in a multivariate expression for maximum likelihood that requires the evaluation of the multiple probability integrals to obtain the maximum likelihood estimates. Also as the number of regressions in the system increases, the model becomes less tractable.

In this paper we propose a Bayesian procedure for estimating a censored demand system using an Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980). Estimating an AIDS model with a Bayesian approach avoids the need to evaluate the multiple probability integrals. The marginal distribution of model parameters and latent shares are simulated by numerical methods. Specifically, we fit the model using the Gibbs sampler. Implementation of the Gibbs sampler involves deriving and then iteratively simulating from the conditional posterior distribution of the model parameters.

The method developed is used to examine the demand for different types of whole grain and non-whole grain breakfast cereals and bars. We use data from 2006 ACNielsen scanner data. Lin and Yen (2007) also found that breakfast was a good source of whole grain. Individuals consumed 40 percent of whole grain at breakfast, compared with 23 percent at lunch and 17 percent at dinner and the rest provided by snack foods. Although scanner data provide information on foods purchased only for at home consumption, because cereals are generally purchased in retail food stores, in case of the breakfast cereals, scanner data is well suited to estimating demand relationships.

The paper is organized as follows. The next section describes the AIDS model and the associated Bayesian posterior simulator. Then data used in the analysis are described, followed by a description of empirical results. The paper concludes with a summary of the findings.

AIDS Model and Posterior Simulator

The AIDS model of Deaton and Muellbauer can be expressed in the latent expenditure share form as:

$$w_{ih}^{*} = \alpha_i + z_{ih}^{'}\delta_i + \sum_{j=1}^{n+1}\gamma_{ij}\ln p_{jh} + \beta_i \ln(y_h / P_h) + \varepsilon_{ih},\ i, j = 1,...,n+1,\ h = 1,...,H \qquad (1)$$

and

$$w_{ih} = \begin{cases} w_{ih}^{*}, & if\ \ w_{ih}^{*} > 0 \\ 0, & if\ \ w_{ih}^{*} \le 0 \end{cases} \qquad (2)$$

where, w_{ih}^{*} and w_{ih} are the latent and observed expenditure shares, respectively, if good *i* of household *h*, p_{jh} is the price of the *j*th good, $z_{ih}^{'}$ is a vector of household specific characteristics, y_h represents total expenditure on *n* goods and P_h is a price index defined as:

$$\ln P_h = \alpha_0 + \sum_{i=1}^{n+1}\alpha_i \ln p_{ih} + \frac{1}{2}\sum_{i=1}^{n+1}\sum_{j=1}^{n+1}\gamma_{ij}\ln p_{ih}\ln p_{jh}\ .$$

The theoretical properties of adding-up, homogeneity and symmetry can be imposed by following parameter restirictions:

$$\sum_i \alpha_i = 1,\ \sum_i \gamma_{ij} = \sum_i \beta_i = \sum_i \delta_{ik} = 0\ ; \quad \sum_j \gamma_{ij} = 0 \quad \text{and} \quad \gamma_{ij} = \gamma_{ji}\ ,\ i \ne j\ ,\ i, j = 1,...,n+1.$$

For household *h* we can express a system of equations, one equation for each good $i = 1,...,n+1$ as

$$\begin{bmatrix} w_{1h}^* \\ w_{2h}^* \\ \vdots \\ w_{(n+1)h}^* \end{bmatrix} = \begin{bmatrix} x_{1h}^{'} & 0 & \cdots & 0 \\ 0 & x_{2h}^{'} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & x_{(n+1)h}^{'} \end{bmatrix} \begin{bmatrix} \theta_1 \\ \theta_2 \\ \vdots \\ \theta_{(n+1)} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1h} \\ \varepsilon_{2h} \\ \vdots \\ \varepsilon_{(n+1)h} \end{bmatrix} \tag{3}$$

where $x_{ih}^{'} = \left[1, z_{ih}^{'}, \ln p_{1h}, \cdots, \ln p_{(n+1)h}, \ln(x_h / P_h)\right]$ is a $1 \times k$ vector and

$\theta_i = \left[\alpha_i \;\; \delta_i^{'} \;\; \gamma_{i1} \cdots \gamma_{i(n+1)} \;\; \beta_i\right]^{'}$ is a $k \times 1$ vector of parameters.

For each household *h* system of equations (3) in stacked form can be rewritten as:

$$w_h^* = X_h \beta + \varepsilon_h, \qquad h = 1, ..., H \tag{4}$$

where $w_h^* = (w_{1h}^*, w_{2h}^*, ..., w_{(n+1)h}^*)'$ and $\varepsilon_h = (\varepsilon_{1h}, ..., \varepsilon_{(n+1)h})^{'} \overset{iid}{\sim} N(0, \Sigma)$ are

$(n+1) \times 1$ vectors, $X_h = diag(x_{1h}^{'}, ..., x_{(n+1)h}^{'})$ is a $(n+1) \times (n+1)k$ and $\theta = (\theta_1^{'}, ..., \theta_{(n+1)}^{'})^{'}$ is

a $(n+1)k \times 1$ vector of parameters. The AIDS model is a seemingly unrelated regressions (SUR) model proposed by Zellner (1962) with the same regressors in each equation. Since the expenditure shares are censored we follow Huang (2001) and estimate SUR Tobit model. Due to the specification of the AIDS model the variance matrix is singular. Hence *n* equations are used in the estimation and the parameters of the dropped equation are recovered from the AIDS adding-up, homogeneity and symmetry restrictions.

To derive the likelihood with censoring, first note that, for each commodity purchase there are 2^n possible combination of censored and uncensored outcomes. Let 2^n possible combinations be represented by the $2^n \times 1$ vector S_r, $r = 1, 2, ..., 2^n$, as

$$S_r = (\underbrace{0, 0, ..., 0}_{l}, \underbrace{+, +, ..., +}_{n-l})'$$

where '0' denotes censored and '+' denotes not censored. The likelihood contribution of household *h* with censoring regime S_r can be state by

$$L_h^{S_r}(w_h;\theta,\Sigma) = \int_{-\infty}^{-x_{1h}^{'}\theta_1} \cdots \int_{-\infty}^{-x_{lh}^{'}\theta_l} L(w_h^*;\theta,\Sigma) dw_{lh}^* \ldots dw_{1h}^*$$

where

$$L(w_h^*;\theta,\Sigma) = (2\pi)^{-n/2} \left|\Sigma^{-1}\right|^{1/2} \exp\left[-\frac{1}{2}(w_h^* - X_h\theta)'\Sigma^{-1}(w_h^* - X_h\theta)\right].$$

The likelihood function which accounts for all censoring combinations of the sample of *H* households is:

$$L(W;\theta,\Sigma) = \prod_{h=1}^{H}\prod_{S_r}\left[L_h^{S_r}(w_h;\theta,\Sigma)\right]^{I_h(S_r)}$$

where $W = (w_1^{'},...,w_h^{'})'$ and $I_h(S_r)$ is an indicator function equal to one if household *h* is in regime S_r and zero otherwise.

We fit this model using recent advances in Markov Chain Monte Carlo (MCMC) technique, namely, the Gibbs sampler.

Assume that the priors are independent and of the form

$$\theta \sim \mathbb{N}(\mu_\theta, V_\theta)$$

$$\Sigma^{-1} \sim W(v_0, \Omega)$$

where $\mathbb{N}$ denotes a multivariate normal distribution and *W* denotes a Wishart distribution. Assume that we have a complete data set y_h, $h = 1,...,H$ where the *i*th element equals w_{ih} if it is not censored and w_{ih}^* if it is censored. Given the assumed priors and the complete data set $Y = (y_1^{'}, ..., y_H^{'})$, the full conditional densities of θ and Σ^{-1} can be derived as

$$\theta \mid w^*, \Sigma^{-1} \sim \mathbb{N}_k(D_\theta d_\theta, D_\theta)$$

$$\Sigma^{-1} \mid w^*, \theta \sim W_i(v_1, R)$$

where

$$D_\theta = (X'(\Sigma^{-1} \otimes I_H)X + V_\theta^{-1})^{-1}$$

$$d_\theta = X'(\Sigma^{-1} \otimes I_H)Y + V_\theta^{-1}\mu_\theta$$

$$R = \left[\Omega^{-1} + (Y - X\theta)'(Y - X\theta)\right]^{-1}$$

and $v_1 = v_0 + H$.

The final step is to simulate the censored data from a multivariate truncated normal distribution. More specifically, we draw from

$$w_{ih}^* \mid w_{1h}^*, w_{2h}^*, ..., w_{i-1h}^*, w_{ih} = 0, w_{i+1h}, ..., w_{nh}, \theta, \Sigma \sim TN_{(-\infty,0]}(\mu_{i|-i}, \sigma_{i|-i}^2)$$

where

$$\mu_{i|-i} = \mu_i + \Sigma_{i-i}^{'}\Sigma_{-i-i}^{-1}(w_{-i}^* - \mu_{-i})$$

$$\sigma_{i|-i}^2 = \sigma_{ii}^2 + \Sigma_{i-i}^{'}\Sigma_{-i-i}^{-1}\Sigma_{i-i}$$

where $TN_{(a,b)}(\mu, \sigma^2)$ denotes a normal distribution with mean μ and variance σ^2 truncated to the interval *(a,b)*, $\mu = X_i\theta$, μ_i is the *i*th row element of μ and μ_{-i} is obtained by deleting the *i*th row element of μ. The matrix Σ_{-i-i} is the $(n-1)\times(n-1)$ matrix derived from Σ by eliminating the *i*th column and row, Σ_{i-i} is the $(n-1)\times 1$ vector derived from the *i*th column of Σ by removing the *i*th row term.

The adding-up and symmetry restrictions are imposed through the prior hyperparameters and homogeneity restriction is automatically satisfied in the AIDS model.

We run the posterior simulator for 50,000 iterations and discard the first 5,000 as the burn-in.

The Data

Scanner Data

We used data from the ACNielsen 2006 Homescan data. The data come from a nationally representative sample of U.S. households that scan their purchased foods at home after each shopping occasion using a scanning device and report the results to the collection firm once a week. The dataset consist of dairy department purchase data, dry grocery department purchase data, UPC produce meat frozen department, and random weight purchase data for 2006. Each of these data has numerous product modules. Each product module was further subdivided into brand, size, flavor, form, formula, container, style, type and variety with each one represented by a unique UPC number. The data also contain the information on purchase date, quantity purchased, price paid deal, price paid non deal, and coupon value.

The 2006 Homescan data consist of over 37,000 households, but only 7,534 households reported purchases of both random-weight and UPC-coded food items. Of these, 7,415 households reported purchases of at least 10 months in 2006. Our final sample comes from the household panel and consists of 7,096 households which had expenditure on cereals at some time during the year.

We matched the household purchases with the household demographic data. The household characteristics include household size, income, age of household head, education and employment of female and male heads, marital status, race, presence of children and region of residence.

Whole Grains Identification

We constructed a dataset for six cereal types: whole grain ready-to-eat, non-whole grain ready-to-eat, whole grain bars, non-whole grain bars, whole-grain hot cereals, and non-whole grain hot cereals. Although the 2005 Dietary Guidelines recommend that Americans eat three or more servings of whole grains per day, by substituting whole grain for refined grains, in the case of whole grains the government offers no straightforward way for consumers to find whole grains products. Manufacturers have begun to label their product on whole grain content and the Whole Grains Council provides an approved stamp to indicate products that are good sources of whole grain. Also, the ACNielsen data contain information on the grain type. We used these three sources to identify cereals as whole grain and non-whole grain: the Whole Grains Council listing, manufacturers' sites and the ACNielsen indicator of grain content.

After merging with our data we found that cereals that the coding did not provide a unique mapping of Universal Product Codes (UPC). To resolve this issue we verified manufacturers' websites and specifically checked if the product was claimed as a whole grain or contained whole grain as a first ingredient. In most cases we were able to identify whole grain products. For example, all General Mills ready-to-eat cereals were carrying a whole grain claim and listed whole grain as a first ingredient. Many websites had information on nutrition facts and ingredients. We identified cereals as whole grain

if the first ingredient listed was whole grain. Again we found some discrepancies in whole grain coding, but resolved them based on evidence from similar products.
Table 1 shows the total number of UPC's by cereal type in our data set and number and percent of cereals identified as whole grain from three sources: scanner data grain type variable, Whole Grain Council and manufacturer's claim. As indicated in the table, we considered 4024 unique UPC product types; most were in the RTE cereal category.

Included in the data were UPC codes for a large number of private label cereals and bars. Private labels represent 61%, 38%, and 68% of total UPC's of ready-to-eat cereals, bars and hot cereals, respectively. Without a manufacturer site, we needed to assign these products to whole grains or not. We developed two classifications. In the first, we coded cereals as whole grain if they (a) carried Whole Grain Council stamp or (b) were identified as a whole grain product by the manufacturer. The remaining products were coded as non-whole grain. In the second classification, we coded products as whole grain if they (a) carried a Whole Grain Stamp, or (b) were identified as a whole grain product by the manufacturer, but the remaining products, including the private labels, were assigned to whole grain if the majority of the observations in the grain type variable were identified as whole grain. That is, if the private label hot cereal indicated the grain type was "rolled oats", then the hot cereal was classified as "whole grain".

Variables and Descriptive Statistics

The price of each commodity was calculated as the unit value, defined as the household expenditure ($) for the product divided by quantity purchased in ounces (reported for the year). The household's expenditure was calculated by subtracting the value of any coupons used during the purchase from the price paid. Although prices were not available for the households not purchasing a particular product, we replaced missing prices with the average prices (unit values) of purchasing households for the corresponding market areas where the household resides. The dataset provide information on 52 Scantrack markets and rural areas. We derived average prices for all six commodities by 52 Scantrack markets and rural areas.

Table 3 presents purchase frequencies, mean expenditure shares, mean expenditures, quantities purchased and unit values for the purchasing households for the commodities used in the analysis. Whole grain ready-to-eat (RTE) cereal was consumed by the majority of the households and also had the highest mean expenditure and expenditure share among different types of cereals. RTE non-whole grain cereals were also purchased by most households. The bars were the least frequently purchased items.

Table 4 presents the definitions of the variables used in the analysis along with the mean and standard deviation of the variables used in the whole sample. The average household income was $59,260. The average household size was 2.34, 23 percent of the sample are households with children, and 59 percent are married couple households. For the analysis reported in this paper, the estimates were unweighted.

Table 5 presents the means and standard deviations for the variables used in the model for the six commodities. The highest average income is for the households who purchased the whole grain bars, an average of $68,520. As indicated in the table, differences exist across product categories. Those making whole grain purchases tended to be higher income and live in the West.

Empirical Results

All the estimations were done using data from classification 2 in Table 2 (the classification that assigned whole grain values to the private label items). A system of six equations was estimated. The sixth equation was omitted due to the specification of the variance matrix for all six equations, and parameters of that equation were obtained through the adding up, homogeneity and symmetry restrictions. The equation omitted during the estimation was the one corresponding to non-whole grain hot cereal. The adding-up property is preserved by letting the sum of the six trend coefficients equal to zero.

Table 6 presents the posterior means and probabilities of being positive for the demographic, price and expenditure related parameters. We find that larger households are less likely to consume any type of whole-grain cereals and more likely to consume non-whole grain ready-to-eat cereals. Households with higher income tend to consume more of whole grain ready-to-eat cereals and less of non-whole-grain ready-to-eat and hot cereals. Households with children present tend to consume non-whole grain ready-to-eat cereals and less of whole grain hot cereals. There are some race/ethnic differences. Compared to others, whites consume more of whole-grain ready-to-eat cereals and less of whole-grain hot and non-whole grain ready-to-eat cereals. All of the own-price parameters had high probability of being positive.

Estimated parameters were used to calculate price and cereal expenditure elasticities in order to examine the responsiveness of the consumers to economic incentives (Table 7). The compensated and uncompensated own-price elastiticities are all negative, consistent with the theory, ranging from -1.921 for non-whole grain hot cereals to -0.578 for whole grain bars. Demand for whole grain bars and non-whole grain hot cereals are noticeably elastic with own-price elasticities of -1.483 and -1.921, respectively.

There exist both substitutability and complementarity among the cereals. Whole grain and non-whole grain ready-to-eat cereals are complements, but whole grain bars and whole grain ready-to-eat cereals are substitutes.

Most of the cross-price elasticities are small. Relatively lower values (in absolute terms) for the cross-price effects indicate that consumers are more responsive to own-price rather than prices of the other goods. The total expenditure elasticities do not vary widely. Total expenditure elasticities are slightly above unity for the whole grain ready-to-eat cereals and whole grain bars, indicating that these are luxury goods.

Discussion and Conclusion

This paper describes a procedure for estimating a censored AIDS model using Bayesian methods. Using ACNielsen 2006 scanner data we estimate demand for breakfast cereals. We disaggregate the cereals by grain type and by type of cereal and estimate the system of 6 equations.

We provide estimated demand parameters for cereals and bar and account for whole grain and non-whole grain products. The estimation procedure we use accounts for censoring in the reported expenditures. Our results show that households are less responsive to price changes for whole-grain and non-whole grain ready-to-eat cereals than for other cereals and bars. Although there are not many other demand estimates in the literature, our results are roughly comparable to those of Jones et al. (2003). They examined seven product categories (breakfast cereal is one of them) which are further subdivided into nutritional classes and found that expenditure elasticity for hot and snack cereals were the highest among cereals. One limitation to our study is the difficulty of assigning a whole grain to the products. In additional extensions to our work, we are examining how sensitive the results are to the classification used. Results from careful examination of detail household data are useful for informing marketing and nutrition education programs, as well as the design of food programs targeted to increasing whole grain product consumption.

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Table 1. Distribution of Cereals and Bars Identified as Whole Grain from Different Sources

	Total UPC's[a]	Designated as Whole Grain by Source					
		Manufacturer		Whole Grain Council[b]		By Grain Type	
	N	N	%	N	%	N	%
RTE	2850	514	18.0	198	6.9	603	21.2
Bar	214	83	38.8	24	11.2	28	13.1
Hot Cereal	960	212	22.1	60	6.3	633	65.9
All	4024						

[a] UPC is Universal Product Code.
[b] Whole Grain Council certification is voluntary.

Table 2. Distribution of All and Whole Grain cereals

	Total UPC's	Classification 1		Classification 2	
	N	N	%	N	%
RTE	2850	519	18.2	938	32.9
Bars	214	84	39.3	147	68.7
Hot Cereal	960	212	22.1	877	91.4
All	4024				

Table 3. Distribution of Households and Sample Mean of Selected Variables

Product Category	No. of Households	% of Households	Mean Expenditure Share	Mean[a] Quantity (ounces)	Mean[a] Expenditure ($)	Mean[a] Unit Value ($/oz)
Sample	7096	100.0				
RTE WG [b]	6328	90.0	0.44	255.8	39.4	0.17
RTE NWG [c]	5960	84.0	0.36	183.1	27.6	0.16
Bars WG	830	11.7	0.02	75.7	11.2	0.17
Bars NWG	517	7.3	0.01	39.2	6.5	0.18
Hot Cereal WG	4414	62.0	0.11	21.8	12.4	0.15
Hot Cereal NWG	1922	27.0	0.06	31.7	6.5	0.11

[a] For purchasing households; [b] WG is Whole Grain; [c] NWG is Non-Whole Grain; RTE is Ready-to-Eat;

Table 4. Definition of Variables, Sample Mean Values and Standard Deviations

Variable	Definition	Mean	Std. Dev.
N	Number of households	7096	
Income/$1000	Household income/$1000	59.26	39.05
Household size	Household size	2.34	1.29
Age of head<30	1 if household head's age is under 30	0.01	0.09
30<Age of head <49	1 if household head's age is between 30&49	0.31	0.46
50<Age of head<64	1 if female head's age is between 50&64	0.40	0.49
65<Age of head	1 if female head's age is 65 and older	0.28	0.45
Presence of children	1 if household has children	0.23	0.42
Male head employed	1 if the male head is employed	0.66	0.47
Female head employed	1 if the female head is employed	0.59	0.49
< High school (male)	1 if the male head's education is high school or less	0.27	0.44
Some college (male)	1 if the male head's education is some college	0.31	0.46
College + (male)	1 if the male head's education is college &post college	0.43	0.49
< High school (female)	1 if female head's education is high school or less	0.27	0.44
Some college (female)	1 if the female head's education is some college	0.31	0.46
College + (female)	1 if female head's education is college &post college	0.42	0.49
Married	1 if married	0.59	0.49
White	1 if race is white	0.77	0.42
Black	1 if the race is black	0.13	0.34
Other	1 if race is other	0.10	0.30
Hispanic	1 if Hispanic	0.07	0.26
East	1 if the household lives in the East region	0.22	0.42
Central	1 if the household lives in the Central region	0.17	0.37
South	1 if the household lives in the South region	0.38	0.49
West	1 if the household lives in the West region	0.23	0.42
Urban	1 if the household lives in urban area	0.87	0.34

Table 5. Variables and Sample Mean Values (N=7096)

	RTE (N=6875)		Bars(N=1183)		Hot Cereal(N=5031)	
Variable	**WG[a]**	**Non-WG[b]**	**WG[a]**	**Non-WG[b]**	**WG[a]**	**Non-WG[b]**
N	6247	6076	830	517	3806	2887
Income/$1000	60.58	59.22	68.52	67.63	62.13	55.93
Household size	2.41	2.43	2.46	2.47	2.41	2.48
Age of head<30	0.01	0.01	0.01	0.01	0.01	0.01
30<Age of head <49	0.32	0.33	0.35	0.33	0.30	0.30
50<Age of head<64	0.40	0.39	0.37	0.39	0.40	0.38
65<Age of head	0.27	0.28	0.27	0.27	0.30	0.31
Presence of children	0.24	0.25	0.25	0.25	0.23	0.25
Male head employed	0.67	0.66	0.70	0.69	0.65	0.63
Female head employed	0.59	0.59	0.59	0.61	0.58	0.55
< High school (male)	0.27	0.28	0.20	0.18	0.26	0.28
Some college (male)	0.31	0.31	0.28	0.27	0.31	0.32
College + (male)	0.43	0.41	0.52	0.54	0.43	0.40
< High school (female)	0.27	0.28	0.22	0.20	0.27	0.28
Some college (female)	0.32	0.32	0.27	0.31	0.33	0.33
College + (female)	0.41	0.40	0.51	0.49	0.40	0.39
Married	0.61	0.61	0.68	0.67	0.63	0.63
White	0.78	0.77	0.78	0.81	0.77	0.79
Black	0.13	0.13	0.09	0.09	0.13	0.13
Other	0.10	0.10	0.12	0.09	0.10	0.08
Hispanic	0.08	0.08	0.08	0.08	0.08	0.08
East	0.23	0.23	0.19	0.25	0.23	0.22
Central	0.17	0.17	0.13	0.16	0.15	0.19
South	0.37	0.38	0.35	0.37	0.37	0.38
West	0.23	0.22	0.34	0.21	0.24	0.21
Urban	0.87	0.87	0.87	0.87	0.88	0.84

[a] WG is Whole Grain, [b] NWG is Non-Whole Grain; RTE is Ready-to-Eat;

Table 6. Censored Demand System: Posterior Means and Probabilities of Being Positive

	RTE				Bars				Hot Cereals			
	WG		NWG		WG		NWG		WG		NWG	
Variables	**E(.|y)**	**Pr(.|y)**	**E(.|y)**	**Pr(.|y)**	**E(.|y)**	**Pr(.|y)**	**E(.|y)**	**Pr(.|y)**	**E(.|y)**	**Pr(.|y)**	**E(.|y)**	**Pr(.|y)**
							Demographic Characteristics					
Intercept	**0.125**	0.98	**0.412**	1.00	-0.354	0.41	-0.066	0.85	**1.452**	1.00	**-0.569**	1.00
Income/$1000	**0.001**	1.00	**-0.002**	0.01	0.004	0.31	0.000	0.91	**-0.001**	0.03	0.002	0.79
Household size	**-0.014**	0.01	**0.021**	0.98	**-0.005**	0.01	**-0.001**	0.01	**-0.068**	0.00	0.067	0.94
Age of head<30	0.067	0.84	0.041	0.61	0.026	0.40	-0.162	0.83	**0.295**	0.94	**-0.267**	0.03
30<Age of head <49	**-0.025**	0.03	**0.050**	1.00	0.014	0.22	**-0.002**	0.91	**0.115**	1.00	**-0.152**	0.04
50<Age of head<64	0.001	0.25	0.009	0.84	-0.005	0.49	0.003	0.95	**0.072**	0.98	**-0.077**	0.03
Presence of children	0.016	0.47	**0.003**	0.94	-0.009	0.14	-0.023	0.94	**-0.026**	0.05	0.018	0.79
Male head employed	0.011	0.13	0.000	0.88	0.018	0.26	-0.001	0.77	**0.083**	0.95	-0.111	0.88
Female head employed	-0.009	0.42	0.010	0.28	-0.012	0.33	0.010	0.96	**-0.025**	0.04	0.035	0.81
< High school (male)	**-0.021**	0.06	**0.033**	0.98	-0.051	0.29	-0.009	0.76	**0.084**	0.95	-0.036	0.35
Some college (male)	-0.012	0.38	0.014	0.24	-0.026	0.26	-0.004	0.71	**0.031**	0.98	-0.002	0.88
<High school(female)	0.002	0.87	0.017	0.45	-0.021	0.32	-0.007	0.76	**-0.094**	0.01	**0.104**	0.01
Some college (female)	0.001	0.91	0.005	0.79	-0.024	0.33	-0.004	0.77	**-0.125**	0.02	0.148	0.35
Married	0.019	0.51	-0.019	0.21	0.047	0.33	0.004	0.83	**-0.121**	0.02	0.070	0.12
White	**0.070**	1.00	**-0.039**	0.03	0.004	0.82	0.002	0.78	**-0.066**	0.00	0.029	0.32
Black	-0.020	0.08	0.019	0.82	**-0.021**	0.10	-0.010	0.81	-0.004	0.35	0.035	0.49
Hispanic	-0.009	0.40	0.015	0.57	**-0.025**	0.06	0.003	0.88	0.001	0.56	0.015	0.76
East	**0.036**	0.90	0.002	0.48	-0.063	0.25	0.006	0.83	-0.009	0.21	0.028	0.21
Central	0.013	0.45	0.015	0.35	-0.069	0.25	-0.003	0.20	0.025	0.94	0.019	0.74
South	0.003	0.13	**0.022**	0.94	-0.059	0.24	0.002	0.89	-0.009	0.12	0.042	0.15
Urban	0.013	0.21	**-0.020**	0.07	-0.006	0.41	-0.004	0.68	-0.017	0.35	0.033	0.82
							Price Coefficients					
RTE WG	**0.095**	1.00										
RTE Non-WG	**-0.063**	0.00	**0.066**	1.00								
Bar WG	**0.004**	0.03	0.001	0.89	**0.010**	0.04						
Bar NWG	**-0.002**	0.20	**-0.004**	0.00	-0.001	0.99	**0.021**	1.00				
Hot WG	**-0.007**	0.00	**-0.020**	0.00	-0.006	0.20	**-0.009**	0.03	**0.038**	**0.00**		
Hot Non-WG	**-0.027**	0.00	**0.020**	1.00	**-0.009**	0.00	**-0.006**	0.00	**0.004**	1.00	**0.019**	1.00
							Total Expenditure					
Expenditure	**0.039**	1.00	**-0.011**	0.00	**0.002**	1.00	**-0.001**	0.05	**-0.022**	0.00	**-0.006**	0.00

RTE is Ready-to-Eat; WG is Whole Grain; NWG is Non-Whole Grain

Table 7. Estimated Demand Elasticities

	RTE		Bars		Hot Cereal	
	WG	**NWG**	**WG**	**NWG**	**WG**	**NWG**
Quantity			*Marshallian Elasticity*			
RTE WG	-0.837	-0.160	0.006	-0.006	-0.027	-0.060
RTE Non-WG	-0.173	-0.788	0.012	-0.012	-0.055	0.060
Bars WG	0.149	-0.005	-1.483	-0.013	-0.309	0.567
Bars NWG	-0.090	-0.262	-0.001	-0.578	-0.595	0.579
Hot WG	0.023	-0.089	-0.040	-0.062	-0.861	0.190
Hot Non-WG	-0.716	0.645	0.342	0.256	0.791	-1.921
			Hicksian Elasticity			
RTE WG	-0.328	0.197	0.028	0.011	0.123	-0.023
RTE Non-WG	0.281	-0.469	0.021	0.012	0.079	0.093
Bars WG	0.658	0.352	-1.461	0.014	-0.159	0.604
Bars NWG	0.355	0.050	0.018	-0.564	-0.464	0.611
Hot WG	0.418	0.188	-0.023	-0.049	-0.745	0.218
Hot Non-WG	-0.433	0.844	0.354	0.266	0.875	-1.901
			Expenditure Elasticity			
	1.083	0.966	1.084	0.947	0.839	0.603

RTE is Ready-to-Eat; WG is Whole Grain