**U.S. Demand for Dairy Alternative Beverages: Attribute Space Distance and Hedonic Matric Approaches**

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***Selected Paper prepared for presentation at the Southern Agricultural Economics Association's 2017 Annual Meeting, Mobile, Alabama, February 4-7, 2016***

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## Abstract

Consumption of dairy alternative beverages in the United States has been growing in the light of decreasing consumption of dairy milk. Although almond milk and soymilk are the fastest growing categories in the U.S. dairy alternative marketplace, there exist numerous other products such as coconut milk, rice milk, cashew nut milk, and hazelnut milk. These plant-based products claim to have more protein and calcium, and less in fat and calories compared to conventional dairy milk, hence perceived growth in consumer preference. Using market level weekly purchase data from 2015 Nielsen scanner panel and attribute space distance and hedonic matric approaches within Barten synthetic model, own-price, cross-price and expenditure elasticities for aforementioned beverage products were estimated. Distance and hedonic variables with regards to product attributes such as calorie, fat, protein, calcium and other nutrients (vitamins and minerals such as iron, vitamin B) are used to estimate, first an n-dimensional distance (hedonic) space based on above qualitative information available to consumers and then this information is allocated to Barten synthetic model to generate demand elasticities using qualitative factor distances. Preliminary analysis revealed following own-price demand elasticities: Soymilk -1.13, almond milk -0.5, and coconut milk -0.46.

Keywords: Dairy alternative beverages, Nielsen data, Distance matric, Hedonic matric, product attributes, Barten synthetic model

*JEL Classification: G11, G12*

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## Background Information

Types of nonalcoholic beverages available to the U.S. consumer has been growing over the past fifteen years, adding increasing levels of functionality and health dimensions. Currently, these beverages are designed not only to quench the thirst, but also to gain numerous vitamins, minerals, proteins, favorable fatty acids (BMC, 2016; Copeland and Dharmasena, 2016). In the light of this availability of plethora of nonalcoholic beverages, dairy alternative (fluid milk alternative) beverages have gained attention among the U.S. consumer. According to Davis *et al*., (2010), USDA-ERS (2013) and Copeland and Dharmasena (2016), per capita consumption in fluid milk in the United States has been dwindling over the past 25 years. This decline in demand and consumption of fluid milk in the United States could be attributed to several reasons, including, but not limited to, Americans becoming more health conscious with respect to beverage choices and look for low-calorie options with increasing variety and flavor in mind, increasing vegan population looking for plant-based protein alternatives (Li and Dharmasena, 2016), etc. Although almond milk and soymilk are the leading categories in the U.S. dairy alternative beverage marketplace, there exist numerous other products such as coconut milk, rice milk, cashew nut milk, and other nut milks such as hazelnut milk. These plant-based products claim to have more protein and calcium, and less in fat and calories compared to conventional fluid milk, hence perceived growth in consumer preference. Although, soy milk was the leader in fluid milk alternative beverage market several years ago (Dharmasena and Capps, 2014), its market share decreased substantially to almond milk, where currently almond milk account for 65% of market share while soy milk has only about 25% of market share (Copeland and

Dharmasena, 2016). Several studies in the extant literature have studied demand and market competitiveness of dairy alternative beverages in the United States, such as Dharmasena and Capps (2014) demand for soymilk, Copeland and Dharmasena (2016) demand for almond milk, and Li and Dharmasena (2016) demand for coconut milk. All of these studies estimated conventional demand models where the underlying utility function of the consumer assumed that the consumer gains utility through consuming aggregated quantity of the desired good. However, when consumer looks for variety with in dairy alternative beverage (such as flavor, nutrients, minerals, fat content, calories), one does not have a demand for the mere quantity of the good, but demand for the desirable characteristics or attributes of the good. This was originally developed by Lancaster (1966) and called “demand in the characteristics goods space”. Berry, Levinsohn and Pakes (1995) implemented the estimation of consumer demand in the characteristics goods space using random coefficient discrete choice model. These random utility models that extend the simulated maximum likelihood approach of Berry, Levinsohn and Pakes (1995) are computationally complex to estimate (Hendel, 1999; Nevo, 2001; Chan 2006). An alternative to this, distance matrix approach, is suggested by Pinske, Slade and Brett (2002) where demand and respective elasticities are estimated in much more simple setting with no simulations involved. However, in this distance matrix method, the choice of distances is ambiguous and depends on prior judgements about data. To overcome that, another method, the hedonic matric approach is proposed by Gulseven and Wohlgenant (2015) where the ambiguity of distance is eliminated while reducing the number of parameters to estimate.

Using weekly household purchase data from Nielsen scanner panel from 2004 through 2015 and attribute space distance and hedonic matric approaches within Barten synthetic model, own-price, cross-price and expenditure elasticities for almond milk, soymilk, coconut milk, and other nut milks are estimated. Distance and hedonic variables with regards to product attributes such as calorie, fat, protein, calcium and other nutrients (vitamins and minerals such as iron, vitamin B) are used to estimate, first an n-dimensional distance (hedonic) space based on above qualitative information available to consumers and then this information is allocated to Barten synthetic model to generate demand elasticities using qualitative factor distances.

The general objective of this study is to investigate U.S. demand for fluid milk alternative beverages using attribute-space distance and hedonic matric approaches.

The specific objectives are to:

(1) Estimate attribute-space hedonic matrix for almond milk, soymilk, coconut milk and other nut milks at brand-level for a pre-identified set of brands of almond milk, soymilk, coconut milk and other nut milks;

(2) Estimate consumer demand for aforementioned fluid milk alternative beverages using Barten Synthetic model;

(3) Delineate demographic factors affecting U.S. demand for almond milk, soymilk, coconut milk and other nut milks.

**Data and Methodology**

Weekly U.S. purchase data, total expenditure and quantity, pertains to purchases of almond milk, soymilk, coconut milk and other nut milks from 2004 through 2015 are collected from Nielsen Homescan database for nearly 65,000 households. Unit value as a proxy for price (ratio of total expenditure to quantity) for each beverage is calculated. From the Universal Product Codes (UPCs) associated with each product type, as recorded in the Nielsen database, is used to identify various nutritional attributes associated with each beverage category. These product attributes are used in allocating each beverage into the hedonic space proposed in this study. Distance and hedonic variables with regards to product attributes such as calorie, fat, protein, calcium and other nutrients (vitamins and minerals such as iron, vitamin B) are used to estimate, first an n-dimensional distance (hedonic) space based on above qualitative information available to consumers and then this information is allocated to Barten synthetic model to generate demand elasticities using qualitative factor distances.

Much of the methodology in this study is based on hedonic metric method proposed in Gulseven and Wohlgenant (2015). First, a hedonic regression is estimated to get the hedonic prices of each qualitative attribute. Hedonic matric approach to demand modeling assumes that the consumer maximizes utility by selecting products that maximizes the sum of the utilities derived from each attribute (Rosen, 1974). Therefore, the price of each beverage in this study can be explained by the set of attributes that come with the product. Therefore, the price of a good and its characteristics vector *x* can be written as follows;

(1) $p = f(x) + e,$

where p is the price of beverage, $x = [x_1, x_2, \ldots \ldots x_k]$. and $e$ is the vector of error.

If the relationship between the price and attribute is linear, then the price of good *i* can be expressed as the sum of values (or shadow prices) of product attributes; the total value of each attribute is the quantity of attribute multiplied by the implicit price of each attribute. That is to say;

$$(2) \qquad P_i = \sum_j x_{ij}\beta_j + E_i + \mu_i$$

where, $x_{ij}$ is the amount of attribute *j* in product *i* and $E_i$ is the unique characteristics of the product. The implicit price of the product is the partial derivative of $P_i$ with respect to $x_j$, which is $\beta_j$. In the linear model, the implicit price of the product attribute is the parameter estimate associated with the quality attribute directly (Akbay et al., 2006). The value added for each attribute now, for linear model is $V_{ij} = x_{ij}\beta_j$. The hedonic distance in terms of a single attribute is calculated as the difference in the value added for each product. Continuous hedonic distance matrix is calculated by combining the sum of price-weighted attribute distances and rescaling them to be between 0 and 1. Also, two products are nearest neighbors if they are located next to each other in the hedonic space. The cross-price effect in the Barten synthetic model now is characterized as follows

$$(3) \qquad \gamma_{ij} = \lambda_h d_{ij}^h + \lambda_{nn} d_{ij}^{nn}$$

where, $d_{ij}^h$ is the hedonic distance, $d_{ij}^{nn}$ is the nearest neighbor dummy matrix. Putting these into the original Barten synthetic model will give rise to the Hedonic Metric approximated Barten synthetic model.

***Barten Synthetic Model***

Barten synthetic system (Barten, 1993) is as follows:

(4) $$w_i d \ln q_i = (\beta_i + \lambda w_i) d \ln Q + \sum_{j=1}^{n} [\gamma_{ij} - \mu w_i (\delta_{ij} - w_j)] d \ln p_j$$

where $i = 1,2,....,n$ and $\beta_i \equiv (1-\lambda)b_i + \lambda c_i$, and $\gamma_{ij} \equiv (1-\mu)s_{ij} + \mu r_{ij}$.

Depending on the restrictions we impose on coefficients $\mu$ and $\lambda$ in equation (4), we could recover the Rotterdam, the LA/AIDS, the CBS and the NBR models. $(\lambda, \mu) = (0,0)$ would yield the Rotterdam model; $(\lambda, \mu) = (1,0)$ would yield the CBS model; $(\lambda, \mu) = (0,1)$ would give rise to the NBR model; $(\lambda, \mu) = (1,1)$ would yield the AIDS model.

To satisfy the theoretical properties associated with the demand theory, we assume following restrictions on parameters of Barten synthetic model. Restrictions imposed are, adding-up:

(5) $$\sum_{i=1}^{n} \beta_i + \lambda = 1$$

(6) $$\sum_{i=1}^{n} \gamma_{ij} = 0,$$

and homogeneity:

(7) $$\sum_{j=1}^{n} \gamma_{ij} = 0, \text{ where } i = 1,2,.....,n.$$

Slutsky symmetry condition is satisfied via the restriction:

(8) $\gamma_{ij} = \gamma_{ji}$ for $i, j = 1,2,......,n$ and $i \neq j$

Expenditure and price elasticity (compensated own- and cross-price elasticities) formulae derived from Barten synthetic model are as follows. Compensated price elasticity formula is expressed as follows:

$$e_{ij}^{C} = \frac{\gamma_{ij}}{w_i} - \mu\left(\delta_{ij} - w_j\right) \tag{9}$$

where $\delta_{ij}$ is the Kronecker delta ( $\delta_{ij} = 1\, if\, i = j$ and $\delta_{ij} = 0\, if\, i \neq j$ ). We recover the uncompensated price elasticities $e_{ij}^{U}$ using the Slutsky derivative expressed in elasticity form as follows:

$$e_{ij}^{U} = e_{ij}^{C} - e_i w_j \tag{10}$$

Next, compensated cross price elasticities were used to assess the symmetry conditions using following expression:

$$e_{ij}^{c} = \left(\frac{w_j}{w_i}\right) e_{ji}^{c} + w_j (e_j - e_i) \tag{11}$$

where $w$'s are budget shares of *i*th and *j*th good and, $e_j$ and $e_i$ are expenditure elasticities of *j*th and *i*th good respectively. Expenditure elasticity formula for Barten synthetic system is given as follows:

$$e_i = \frac{\beta_i}{w_i} + \lambda \tag{12}$$

## Preliminary Results

Once the hedonic matrix is developed, it will reveal the value added for each product characteristic, which will be important to explain the contribution of each attribute to the price (or the value) of the good under consideration. In the second step of the estimation, the price parameter associated with Barten synthetic model is replaced with price weighted hedonic distance matrix to uncover traditional cross and own-price elasticity estimates. Preliminary analysis revealed that the own-price elasticity of demand for soymilk is -1.13, and that of almond milk is -0.5, and coconut milk at -0.46.

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