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# Consumer Demand for Nut Products in the United States: Application of Semi-parametric Estimation of Censored Quadratic Almost Ideal Demand System (C-QUAIDS) with Household-Level Micro Data

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# Consumer Demand for Nut Products in the United States: Application of Semi-parametric Estimation of Censored Quadratic Almost Ideal Demand System (C-QUAIDS) with Household-Level Micro Data

Senarath Dharmasena and Oral Capps, Jr.

## Abstract

The United States is a dominant player in the world tree nut production with the value of nuts produced exceeded $10 billion by 2015. Annual per capita consumption of nuts in the United States has been growing during past 25 years due to increase in nutrition and health benefits of nuts. Few studies that looked at the economics of nuts in the United States come short in examining demand interrelationships between various tree nut products and peanuts to uncover complex substitutability/complementarity patterns through derivation of own-price, cross-price and income/expenditure elasticities. Demographic factors affecting the consumer demand for nut products is yet to be investigated as well. Quantity, expenditure and household demographic characteristics with respect to purchase of almonds, pecans, walnuts, pistachios, cashew nuts and peanuts obtained from 2014 Nielsen Homescan scanner panel for 65,000 U.S. households was used in estimating censored quadratic almost ideal demand system using semiparametric estimation procedure suggested by Sam and Zheng (2010). Preliminary results show that the own-price elasticity of demand for almonds, pecans, walnuts, pistachios, cashew nuts and peanuts is -0.75, -0.98, -1.05, -0.53, -0.56, and -0.17. Income, age, region and presence of children are significant drivers of demand for these nut products.

Keywords: Consumer demand, nut products, censored demand, semi-parametric estimation

*JEL Classification: D11, D12*

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**Background Information:**

Nuts are high in unsaturated fat and low in saturated fat, and considered a high-energy food abundant in dietary fiber, vitamins, minerals and essential fatty acids, etc. (USDA-ARS, 2016). United States is a dominant player in the worlds' tree nut production, specifically almonds, hazelnuts, walnuts, macadamias, pistachios and pecan. The total value of nuts produced in the United States exceeded $10 billion by the end of 2015 (USDA-ERS, 2015). Given the high nutritive value and dietary fiber content with regards to nuts, annual per capita consumption of nuts in the United States have been growing during the past twenty five years, and as of 2015 it was 4.30 pounds, a 240% growth since 1980 (USDA-ERS, 2015). Given this backdrop, we could only find few studies in the extant literature which examined the economics of nut products in the United States. Florkowski (1997) and Ibrahim and Florkowski (2007) studied co-integration relationships between pecan and other edible nuts in the United States to uncover long-run price relationships. Lin *et al*., (2001) examined U.S. consumption patterns of tree nuts using 1994-96 Continuing Survey of Food Intake by Individuals (CSFII) database. In this study, authors grouped tree nut consumption by different demographic factors and income of U.S. households. O'Neil et al., (2010) conducted an epidemiological study to assess association between tree nut consumption and nutrient intake and diet quality using 1999-2004 National Health and Nutrition Examination Survey (NHANES) data. However, all of aforementioned studies come short in examining demand interrelationships between various tree nut products and peanuts in the United States to uncover complex substitutability/complementarity patterns through derivation of own-price, cross-price and income/expenditure elasticities using actual food purchase data (vis-

a-vis diet recall data). Furthermore, a comprehensive set of demographic factors affecting the consumer demand for nut products in the United States is yet to be investigated. This knowledge of price sensitivity, substitutes and complements and demographic profiling in particular is important for manufacturers, retailers and advertisers of these nut products from a competitive intelligence standpoint and making strategic decisions. In this censored demand system analysis, we use expenditure, quantity and demographic information obtained from 2014 Nielsen Homescan scanner panel. Novelty also spans across the application of semiparametric estimation procedure suggested by Sam and Zheng (2010) in estimating censored quadratic almost ideal demand system (C-QUAIDS) with household-level micro data.

The general objective of this study is to determine demand interrelationships between almonds, pecans, walnuts, pistachios, cashew nuts and peanuts using C-QUAIDS estimated using semiparametric procedure suggested by Sam and Zheng (2010). Specific objectives are to:

(1) Estimate compensated and uncompensated own-price and cross-price elasticities, and expenditure elasticities for almonds, pecans, walnuts, pistachios, cashew nuts and peanuts;

(2) Determine demographic factors affecting the purchase of almonds, pecans, walnuts, pistachios, cashew nuts and peanuts by representative U.S. households.

**Data and Methodology**

We use quantity, expenditure and household demographic characteristics with respect to purchase of almonds, pecans, walnuts, pistachios, cashew nuts and peanuts obtained from 2014 Nielsen Homescan scanner panel. This panel consists of approximately 65,000 representative households from across the United States. Given the nature of censoring present in the data, this paper uses a two-step semi-parametric approach suggested by Sam and Zheng (2010) for the estimation of censored demand system. This method is exempt from distributional misspecification (does not assume a normally distributed error in the first-stage equation) and accommodates a certain form of heteroskedasticity. We use the Klein and Spady (1993) semi-parametric single-index model instead of the conventional probit model used in alternative two-step estimators such as Shonkwiler and Yen (1999) in the first-stage equation to model the decision to purchase any nut type. The advantage of the Klein and Spady (1993) model is that, without relying on distributional assumptions, this method generates consistent and efficient estimates and furthermore accommodates heteroskedasticity of a certain form in the error term. In the second stage, the QUAIDS (Banks *et al*, 1997) is used to model the conditional demand for almonds, pecans, walnuts, pistachios, cashew nuts and peanuts.

Methodology explained below is from Sam and Zheng (2010). For *n* goods and *j* (cross-sectional) observations, binary (0-1) $(d_{ij})$ indicator function *I* can be expressed as follows:

(1) $$d_{ij} = I(W_{ij}'\gamma_i + v_{ij})$$

where $W_{ij}'$ is vector of regressors, $\gamma_i$ is model parameter and $v_{ij}$ is zero mean and finite variance error process. The conditional response variable, $Y_{ij}$ in the second-stage equation is as follows:

(2) $$Y_{ij} = d_{ij} * (g(X_{ij}, \beta_i) + \epsilon_{ij})$$

where $X_{ij}$ is vector of regressors, $\beta_i$ is model parameter and $\epsilon_{ij}$ is zero mean and finite variance error. Given equations (1) and (2), the conditional mean can be expressed as follows:

(3) $$E\left(Y_{ij}\middle|X_{ij},W_{ij}\right)=E\left(Y_{ij}\middle|X_{ij},W_{ij};d_{ij}=1\right)*prob(d_{ij}=1).$$

The unknown cumulative distribution function of the error term $v_{ij}$ is denoted by $F_i(W_{ij}'\gamma_i)$. Then we can write the system of equations of interest as follows:

(4) $$Y_{ij}=\left(\ g\left(X_{ij},\beta_i\right)+\lambda_i\left(W_{ij}'\gamma_i\right)\right)*F_i\left(W_{ij}'\gamma_i\right)+\eta_{ij}.$$

The parameters of the first step are estimated using Klein and Spady (1993) semiparametric single-index model. The second stage conditional demand system (the QUAIDS model) can be expressed as follows: $w_i$ is the budget share of dairy product; $a(P)$ is the Translog price index; $b(P)$ is the Cobb-Douglas price index; $m$ is total expenditure; $p$ is price of dairy product:

(5) $$w_i=\left(\alpha_i+\beta_i\left(ln\frac{m}{a(P)}\right)+\sum_{k=1}^{n}\gamma_{ik}lnp_k+\sum_{l=1}^{L}\tau_{il}\left(W_i'\widehat{\gamma_l}\right)^{l-1}+\frac{\lambda}{b(P)}\left(ln\frac{x}{a(P)}\right)^2\right)*$$
$$\widehat{F_l}(W_i'\widehat{\gamma_i})$$

**Preliminary Results**

Once estimated, we will be in position to estimate uncompensated and compensated own-price, cross-price elasticities and expenditure elasticities for the separable group of nut products, namely almonds, pecans, walnuts, pistachios, cashew nuts and peanuts. Also, we will be profiling demographic characteristics of consumers with regards to these food groups. Preliminary analysis of data reveal that the own-price elasticity of demand for almonds, pecans, walnuts, pistachios, cashew nuts and peanuts is -0.75, -0.98, -1.05, -0.53, -0.56, and -0.17

respectively. Market penetration for almonds, pecans, walnuts, pistachios, cashew nuts and peanuts was estimated to be a 14%, 7%, 8%, 6%, 9% and 19%. Income, age, region and presence of children are significant drivers of demand for these nut products.

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