Demand for Differentiated Vegetables

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Abstract. To obtain a healthier diet, Americans need to consume not only more vegetables, but also a healthier mix of vegetables. Household demands for eight categories of vegetables are investigated, using ACNielsen's Homescan data. A maximum simulated likelihood estimation procedure results in elasticity estimates which are somewhat larger than those obtained from both time-series and cross-section data in the literature. Even these larger elasticities are not large enough to bridge the dietary consumption gap without, and possibly even with, substantial price or food expenditure subsidies. Furthermore, Homescan data do indicate some significant differences in preferences for types of vegetables by household characteristics, such as race and ethnicity. This information could be used in designing more effective public interventions for boosting vegetable consumption in the United States.

Key words: censored dependent variables, differentiated vegetables, Homescan data.

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Introduction

Responding to a growing body of evidence for an association between increased vegetable and fruit consumption and a reduced risk of cancer and other diseases, the U.S. Government has recommended its citizens incorporate more fruits and vegetables in their daily diets. The National 5-A-Day for Better Health Program was initiated as a public-private partnership in 1991 to increase the consumption of fruits and vegetables in the United States to 5-to-9 servings every day (NIH-NCI). In 1992, the U.S. Department of Agriculture released the Food Guide Pyramid to recommend consuming a minimum of 3 servings of vegetables and 2 servings of fruits each day (USDA-HNIS). It was estimated that “a simple change, such as eating the recommended five servings of fruits and vegetables each day, could by itself reduce cancer rates more than 20 percent” (WCRF, p. 540).

Still, Americans are not consuming the recommended servings of fruits and vegetables. Data from the most recent USDA food consumption survey indicate that Americans consumed 1.5 servings of fruits and 3.4 servings of vegetables during 1994-96 (Krebs-Smith and Kantor). The recommended servings vary among individuals according to caloric requirements, and averaged 3.2 servings of fruits and 4.2 servings of vegetables for Americans during 1994-96. Only 17 and 31 percent of Americans consumed the recommended servings of fruits and vegetables, respectively (Bowman et al.). Low-income consumers were even less likely to meet the daily recommendations than their higher-income counterparts (Krebs-Smith and Kantor).

Further, the type of vegetables consumed also deviated from the recommended patterns. USDA recommends that dark-green and deep-yellow vegetables should account for 35 percent of total consumption, and starchy vegetables another 35 percent (Kantor, p. 16). Of the 3.4 servings of vegetables consumed, dark-green and deep-yellow vegetables represented 0.4 serving (12 percent) and potatoes alone accounted for 1.1 servings (32 percent). Therefore, a healthier diet would include not only more vegetables, but also a different mix in favor of nutrient-dense vegetables.[1]

The fruit and vegetable industry and the public health community have a shared interest in increasing fruit and vegetable consumption, and the potential health care savings suggest government intervention could be justified on benefit-cost basis. Certain strategies have been attempted by the Federal Government, such as the WIC Farmers' Market Nutrition Program and the Senior Farmers' Market Nutrition Program and informational campaigns (USDA-FNS). A recent Federal pilot program also provided free fruits and vegetables in schools in several States (Buzby, Guthrie and Kantor). Designing effective promotional or marketing strategies rests, however, on knowledge of how consumption of fruits and vegetables is likely to respond to various forms of intervention, such as diet and health information, or economic incentives such as price or income subsidies. Without such knowledge, public interventions can be ineffective and can lead to a wasteful use of public resources.

Data

The demand for vegetables is the focus of this study. Demand elasticities for several categories of vegetables are estimated by applying appropriate econometric techniques to data reported by ACNielsen's Homescan panel, a nationally representative panel of U.S.

households, which provides food purchase data for at-home consumption. At home, a panel household scanned in either the Uniform Product Code (UPC) or a designated code (for random weight food items) for all of their purchases at all retail outlets. The data include detailed product characteristics, quantity, expenditures, and promotion information for each food item purchased by the household. Detailed household demographics are also available in Homescan. Therefore, Homescan data are ideal for estimating household food demands for home consumption.

The full Homescan panel consists of more than 50,000 households, but only 12,000 households reported both random weight and UPC purchases in 1999. We use data from 7,195 of these households, which reported purchases for at least 10 months in 1999. These households are segmented into low- and high-income samples in this study. The household income and household size are used to express household income as a percent of the Federal poverty level, and a cutoff of 300 percent of the FPL is used so that the sample distribution is more even between the two income groups.

Vegetables are available in various product forms, including fresh, frozen, dehydrated, and canned. Consumers can also purchase processed foods, such as frozen ready-to-eat meals, which contain vegetables as ingredients. In this study, vegetables included as ingredients in mixtures are excluded. Vegetables purchased for at-home consumption are aggregated into eight categories, according to their product forms, nutritional profile, and market shares. There are two product forms (fresh and processed), and for each product form there are four types of vegetables (dark-green and deep-yellow, potatoes, tomatoes, and others). Individual food items purchased were reported by each household, and these items were aggregated into the eight vegetable categories and then totaled to the annual basis.

Vegetable Demand Elasticities

Vegetable demands have been estimated previously using both time-series and cross-sectional data. Using USDA's per-capita food disappearance data, Huang fitted a demand system of 39 commodities, including five vegetables, and found vegetable demands are own-price and expenditure inelastic. The own-price elasticities ranged from a low of –0.08 for celery and –0.09 for lettuce to –0.62 for tomatoes, while the expenditure elasticities ranged from 0.08 for onions to 0.92 for tomatoes. Vegetable demands have also been estimated using cross-sectional data from the Bureau of Labor Statistics' Consumer Expenditure Diary Survey (CES) and USDA's food consumption surveys. Using the CES data, Feng and Chern reported, for fresh and processed vegetables respectively, own-price elasticities of –0.61 and –0.56 and expenditure elasticities of 0.87 and 0.62. Raper, Wanzala and Nayga aggregated fruits and vegetables and reported higher own-price (unitary) and expenditure (0.88) elasticities for both poverty and non-poverty households. Using the 1977-78 Nationwide Food Consumption Survey (NFCS) data, Cox and Wohlgenant found that the demand for frozen vegetables was much more own-price elastic than for fresh and canned vegetables (–0.67 versus –0.20). The 1987-88 NFCS household data were also analyzed with income-segmented samples (Huang and Lin; Park et al.). Treating vegetables as a single commodity, Huang and Lin reported higher own-price and expenditure elasticities than Park et al. For example, for low-income households Huang and Lin reported an own-price elasticity of –0.70 and an expenditure elasticity of 1.03, compared with –0.32 and 0.38 reported by Park et al.

The contributions of this study are twofold: to apply an appropriate econometric estimation technique to a new food consumption data set which, perhaps due to typical censoring in the data, remains fairly little used by demand analysts; and to estimate elasticities for vegetables in categories that conform more closely to Dietary Guidelines and Food Guide Pyramid categories. Like several previous studies, the data are segmented to allow for separate elasticity estimates for low and higher income households. The income breakdown is important because the Federal government's food assistance programs target low-income consumers and, in theory, the food assistance programs could be modified to emphasize fruit and vegetable consumption. For example, "green food stamps" could be issued, or the WIC food package could be revised to put more emphasis on fruits and vegetables.

The Translog Demand System

Consider utility function $U(\mathbf{q})$ where $\mathbf{q} \equiv [q_1, q_2, ..., q_n]'$ is an n-vector of vegetable products, weakly separable from all other goods, with prices $\mathbf{p} \equiv [p_1, p_2, ..., p_n]'$. Assuming $U(\mathbf{q})$ is monotonic and regular strictly quasi-concave in $\mathbf{q}$, the consumer-choice problem is summarized by the indirect utility function

(1) $$V(\mathbf{p}, m) = \max_{\mathbf{q}} \{U(\mathbf{q}) \mid \mathbf{p}'\mathbf{q} \le m\},$$

where m is total vegetable expenditure. We use the Translog indirect utility function (Christensen, Jorgensen and Lau)

(2) $$\log V(\mathbf{p},m) = \alpha_0 - \sum_{i=1}^{n} \alpha_i \log(p_i / m) - \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \beta_{ij} \log(p_i / m) \log(p_j / m).$$

Applying Roy's identity to (2) and imposing the normalization rule $\sum_{i=1}^{n} \alpha_i = 1,$ yields the Translog demand system in share form, denoted $s_i(\theta)$:

(3) $$s_i(\theta) = \frac{\alpha_i + \sum_{j=1}^{n} \beta_{ij} (p_j / m)}{1 + \sum_{k=1}^{n} \sum_{j=1}^{n} \beta_{kj} \log(p_j / m)}, \quad i = 1, 2, ..., n,$$

where θ is a vector containing demand parameters α's and β's. Homogeneity is implicit in the utility function (2) and share equations (3), and the symmetry restrictions $\beta_{ij} = \beta_{ji}$ $(\forall\ i, j)$ are also imposed. Demographic variables d_k are incorporated in (3) by parameterizing α_i such that $\alpha_i = \alpha_{i0} + \sum_k \alpha_{ik} d_k$ $(i = 1, 2, ..., n)$, where α_{i0} and α_{ik} are parameters. Appending an error term ε_i to each deterministic share,

(4) $$w_i^* = s_i(\theta) + \varepsilon_i, \quad i = 1, 2, ..., n,$$

completes the stochastic specification.

Censoring and the Likelihood Function

The consumer choice (1) is subject to nonnegativity constraints of quantities q_i, and therefore observed consumption shares are subject to censoring. A number of statistical procedures exist in the literature which accommodate censored dependent variables in a consumer demand system (Lee and Pitt; Wales and Woodland). The approach used in this study, also used in Yen, Lin and Smallwood and Yen and Huang, is a nonlinear generalization of the multivariate linear Tobit system (Amemiya). In this approach, observed shares w_i relate to latent shares w_i^* such that

(5) $$w_i = \max\{w_i^*, 0\}, \quad i = 1, 2, ..., n.$$

To accommodate the adding-up restriction we follow the approach in Yen, Lin and Smallwood, suggested by Pudney (p. 155), in estimating the first *n*–1 equations in the system (5). Then, demand elasticities for *n*th good can be calculated using the adding-up property (Yen, Lin and Smallwood, p. 460).

Consider a regime in which the first ℓ goods are consumed, with observed (*n*–1)-vector $w = [w_1^*, ..., w_\ell^*, 0, ..., 0]'$. Denote the random error vector as $\xi \equiv [\xi_1', \xi_2']'$, partitioned such that $\xi_1 \equiv [\varepsilon_1, ..., \varepsilon_\ell]'$, $\xi_2 \equiv [\varepsilon_{\ell+1}, ..., \varepsilon_{n-1}]'$ and assume ξ is distributed as (*n*–1)-variate normal with zero mean and covariance matrix $\Sigma \equiv [\rho_{ij}\sigma_i\sigma_j]$, where ρ_{ij} are error correlation coefficients and σ_i are standard deviations. Denote $\mathbf{u} \equiv [-s_{\ell+1}(\theta), -s_{\ell+2}(\theta), ..., -s_{n-1}(\theta)]'$. Then, the censor mechanism (5) implies the regime-switching condition

$$\xi_2 \leq \mathbf{u},$$

from which the likelihood contribution of this demand regime can be constructed as

(6) $$L_c(w) = g(\xi_1) \int_{\{\xi_2 : \xi_2 \leq \mathbf{u}\}} h(\xi_2 \mid \xi_1)\, d\xi_2,$$

where $\xi_1 \equiv [w_i - s_i(\theta)]$ is a ℓ-vector, $g(\xi_1)$ is the marginal density of ξ_1, and $h(\xi_2 \mid \xi_1)$ is the conditional density of ξ_2 given ξ_1 (Yen, Lin and Smallwood). The sample likelihood function is the product of the likelihood contributions (6) over the sample.

To accommodate censoring of the demand shares, elasticities are calculated from the unconditional mean of the dependent variables. The unconditional mean of w_i is

(7) $$E(w_i) = \Phi[s_i(\theta)/\sigma_i]s_i(\theta) + \sigma_i\phi[s_i(\theta)/\sigma_i],$$

where $\phi(\cdot)$ and $\Phi(\cdot)$ are univariate standard normal probability density function (pdf) and cdf, respectively (Maddala). Demand elasticities are derived by differentiating (7); see, e.g., Yen and Huang for elasticity formulas.

Descriptive Statistics

Sample statistics of the data are presented in table 1. Quantities are expressed in dried ounces (oz) and prices in cents. There are 2,182 households in the low-income group and 4,126 in the high-income group. The low-income sample is larger and more likely to have children than the high-income sample. Relative to their low-income counterparts, high-income households spent more on all four categories of fresh vegetables, more on processed dark-green/deep-yellow and other vegetables, but less on processed potatoes and processed tomatoes; these high-income households also purchased a larger quantity of fresh vegetables but a smaller quantity of processed vegetables. High-income households paid a higher price for all eight categories of vegetables than low-income households.

Also presented in table 1 are the proportions of consuming households for the eight vegetables considered. For the low-income households, the proportion of consuming households ranges from 69 percent for fresh potatoes to 99 percent for other processed vegetables. For the high-income group, the proportion of consuming households is higher than for the low-income households for all vegetables except processed potatoes. Among the eight vegetables considered, four contain 20 percent or more zeros for both the low- and high-income households. A total of 196 low-income households (or about 9 percent of the sample) contain four or more zeros among the eight vegetables. For the high-income households, that proportion is slightly lower (6 percent).

Results

The Translog demand system was fitted with the low-income and high-income samples. For households reporting zeros in four vegetables or more, the likelihood function is evaluated with a smooth probability simulator (Hajivassiliou; Yen, Lin and Smallwood), using 300 replications. In addition to prices and total (vegetable) expenditure, the econometric model also incorporates household characteristics, including household size, presence of children, household type (headed by a female or not), race and ethnicity, and region. Parameter estimates for the low- and high-income households are presented in tables 2 and 3, respectively. For the low-income households, nearly one half (or 32) of the 70 demographic parameters are significant, one third (12) of the 36 quadratic price coefficients, and all but three of the 21 error correlation coefficients are significant, at the 5-percent level or lower. The significance of the demographic variables justifies the use of these variables in explaining heterogeneity of preference, while significance of the error correlation coefficients justifies estimation of the demand equations in a system (besides the need to impose cross-equation restrictions). The proportion of significant parameter estimates is even higher for the high-income sample, most likely due to the larger sample size for the high-income group.

Our parameter estimates show that households headed by a female in both low- and high-income groups tend to purchase more fresh vegetables for home consumption than other households. Compared with households of other race/ethnicity, White and

Black households purchase less fresh dark-green/deep-yellow and other vegetables but more processed dark-green/deep-yellow vegetables and potatoes. Hispanic households purchase more tomatoes, fresh and processed, for home consumption, compared with households of other race/ethnicity. Low-income Hispanic households purchase fewer fresh potatoes and other vegetables and high-income Hispanic households purchase less fresh dark-green/deep-yellow and other vegetables, compared with their respective income groups of other race/ethnicity

All own-price elasticities are significant at the 1-percent level for both income groups (tables 4-5). Importantly, our results suggest that low-income households are more responsive to changes in vegetable prices than high-income households. The own-price elasticities for low-income households range from a low of –0.91 for other fresh vegetables to a high of –1.27 for fresh potatoes, compared to a range of –0.76 for fresh tomatoes to –0.98 for processed potatoes for high-income households. All expenditure elasticities are also significant at the 1-percent level. The demands for all four categories of fresh vegetables are more responsive to expenditure than their processed counterparts for both low- and high-income households. Furthermore, vegetable purchases of low-income households are more responsive to changes in expenditure, compared to purchases of high-income households. For example, the expenditure elasticities are 1.32 and 1.27 for fresh dark-green/deep-yellow vegetables, and 1.10 and 1.00 for processed dark-green/deep-yellow vegetables, among low- and high-income households, respectively. Other processed vegetables have the lowest expenditure elasticities (0.74 for high-income and 0.76 for low-income households).

Relative to the own-price and expenditure elasticities, the cross-price effects are notably smaller for both low-income and high-income households, with most elasticities under 0.30 (in absolute values). In addition, while the elasticities suggest a mixture of gross complements and substitutes, most significant compensated cross-price elasticities are positive (with only a few exceptions), suggesting that net substitution is the obvious pattern among the vegetables.

Our elasticity estimates are somewhat larger than those obtained from both time-series and cross-section data in the literature. One reason may be that vegetables are disaggregated into eight categories in this study, compared to only one category in Huang and Lin. Our elasticity estimates indicate that consumers would increase their vegetable consumption as a response to lower prices, but still not by a lot. With own-price elasticities of about unity, proportional changes in prices and quantities demanded would be expected. Take the dark-green/deep-yellow vegetable as an example, Americans consumed only 0.4 servings a day, as compared to the recommended 1.5 servings (35 percent of the recommended total of 4.2 servings).

Implications

This study finds slightly higher price and expenditure elasticities than those reported in the literature, although in most cases demand is inelastic. Even these larger elasticities are not large enough to bridge the dietary consumption gap without, and possibly even with, substantial price or food expenditure subsidies. Nonetheless, the finding that low-income households exhibit more responsiveness to prices suggests that fruit and vegetable policy could be more cost-effective if targeted to this group. Furthermore, the Homescan panel data indicate some significant differences in preferences for types of vegetables among the different racial/ethnic groups, and this information could be used to design and target diet and health messages to reflect these differences. The results also suggest that if price subsidies of some form are used, they should probably be combined with other strategies such as information campaigns to enhance their potential impact. It is also possible that price or expenditure subsidies in controlled environments could be more effective than our elasticities suggest. Elasticities reported from demand analyses differ substantially from findings based on experiments conducted in school cafeterias. By reducing the cafeteria prices of fruits, carrots and salads by 50 percent with minimal promotion, French et al. found that sales of fruits and carrots increased by fourfold and twofold, respectively. The sale of salad did not change significantly. The experiment was carried out in a unique environment–high school cafeterias–and the three reduced-price items were among limited choices available on a la carte menu. Facing drastic price changes, students were enticed to switch their choices (corner solutions) instead of making marginal adjustments. Therefore, it is doubtful that the experimental results could be extrapolated to the market place where consumers are presented with a spectrum of food choices.

Finally, this study shows that the nonlinear generalization of the multivariate linear Tobit system can be successfully applied to the ACNielsen Homescan panel data in order to estimate a flexible and utility-theoretic food demand system. The potential for new insights into food demand behaviors based on this and similar household panel data sets is tremendous.

Footnote

1 Dietary guidance suggests that consumers divide their total vegetable servings into three subgroups: dark-green leafy and deep-yellow vegetables; starchy vegetables, including potatoes, dry beans, peas, and lentils; and other vegetables, including iceberg lettuce and tomatoes (Putnam, Allshouse and Kantor).

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Table 1. Sample Statistics

	Low-Income Sample			High-Income Sample		
Variable	Proportion Consuming	Mean	Std. Dev.	Proportion Consuming	Mean	Std. Dev.
Expenditures ($ / year)						
Fresh dark-green-deep-yellow (Fresh dg-dy)	0.72	6.35	10.40	0.79	9.53	14.48
Processed dark-green-deep-yellow (Proc. dg-dy)	0.72	5.78	8.96	0.75	6.52	9.72
Fresh potatoes	0.69	5.94	10.49	0.78	7.71	11.44
Processed potatoes[a] (Proc. potatoes)	0.85	15.80	20.61	0.82	13.54	17.49
Fresh tomatoes	0.82	9.29	13.31	0.86	12.29	16.82
Processed tomatoes (Proc. tomatoes)	0.76	5.68	9.01	0.77	5.39	7.56
Other fresh vegetables (Other fresh)	0.97	31.44	34.24	0.98	41.58	43.36
Other processed vegetables (Other proc.)	0.99	41.65	35.08	0.99	42.73	34.71
Quantities (oz. / year)						
Fresh dark-green-deep-yellow		114.26	179.10		162.67	458.16
Processed dark-green-deep-yellow		99.97	156.71		96.93	139.81
Fresh potatoes		200.87	374.54		225.59	332.49
Processed potatoes[a]		231.91	302.12		178.57	245.33
Fresh tomatoes		136.83	209.46		155.92	214.21
Processed tomatoes		153.75	238.91		139.47	201.91
Other fresh vegetables		648.80	696.43		753.44	765.47
Other processed vegetables		955.18	842.99		838.52	719.41
Prices (cents / oz.)						
Fresh dark-green-deep-yellow		6.12	2.11		6.62	2.70
Processed dark-green-deep-yellow		6.58	2.40		7.22	2.66
Fresh potatoes		3.45	1.14		3.67	1.10
Processed potatoes[a]		8.29	3.93		9.11	4.25
Fresh tomatoes		7.46	2.32		8.27	2.68
Processed tomatoes		4.07	1.23		4.25	1.31

Other fresh vegetables	5.10	1.56	5.67	1.77
Other processed vegetables	4.81	1.89	5.66	2.23
Household size	2.97	1.61	2.55	1.15
Children ≥ 18	0.43	–	0.28	–
Female headed	0.34	–	0.21	–
Hispanic	0.08	–	0.06	–
White	0.82	–	0.85	–
Black	0.10	–	0.10	–
Other race (reference)	0.08		0.05	
East	0.20	–	0.21	–
Central	0.29	–	0.24	–
South	0.30	–	0.36	–
West (reference)	0.21		0.19	
Sample size	2182		4126	

[a] Potato chips excluded.

Source: ACNielsen's Homescan panel, 1999.

Table 2. Maximum Simulated Likelihood Estimates of Translog Demand System: Low-Income Households

Variables	Fresh dg-dy	Proc. dg-dy	Fresh potatoes	Proc. potatoes	Fresh tomatoes	Proc. tomatoes	Other fresh
Demographic variables (α_{ij})							
Constant	–0.024	–0.055‡	–0.001	0.057*	–0.015	–0.010	0.319‡
	(0.019)	(0.019)	(0.018)	(0.034)	(0.022)	(0.018)	(0.030)
Household size	–0.004	–0.000	–0.007‡	0.005	–0.004	0.003	–0.006
	(0.003)	(0.003)	(0.003)	(0.005)	(0.003)	(0.003)	(0.005)
Children ≥ 18	–0.012	0.003	–0.031‡	0.100‡	–0.012	0.001	–0.073‡
	(0.008)	(0.008)	(0.008)	(0.014)	(0.009)	(0.007)	(0.015)
Female head	0.026‡	0.006	0.011	–0.019*	0.018‡	–0.009	0.056‡
	(0.007)	(0.007)	(0.007)	(0.012)	(0.007)	(0.006)	(0.012)
Hispanic	–0.019	–0.002	–0.037‡	–0.016	0.038‡	0.047‡	–0.043†
	(0.012)	(0.013)	(0.013)	(0.021)	(0.014)	(0.011)	(0.018)
White	–0.025†	0.024*	–0.014	0.110‡	0.005	–0.006	–0.099‡
	(0.012)	(0.013)	(0.013)	(0.023)	(0.015)	(0.012)	(0.020)
Black	–0.042‡	0.071‡	0.027*	0.069‡	–0.035*	–0.004	–0.114‡
	(0.015)	(0.015)	(0.015)	(0.026)	(0.018)	(0.013)	(0.025)
East	–0.014*	0.050‡	–0.019†	–0.002	–0.010	0.013*	–0.086‡
	(0.008)	(0.010)	(0.009)	(0.013)	(0.009)	(0.008)	(0.015)
Central	–0.036‡	0.022†	–0.025‡	0.036‡	–0.016†	0.010	–0.105‡
	(0.008)	(0.009)	(0.008)	(0.012)	(0.008)	(0.007)	(0.016)
South	–0.036‡	0.045‡	–0.005	–0.008	–0.013	0.005	–0.119‡
	(0.008)	(0.010)	(0.008)	(0.013)	(0.009)	(0.007)	(0.017)
Quadratic prices (β_{ij})							
Fresh dg-dy	0.001						
	(0.008)						
Proc. dg-dy	–0.001	–0.026‡					
	(0.005)	(0.009)					
Fresh potatoes	–0.018‡	–0.003	–0.030‡				
	(0.005)	(0.005)	(0.008)				
Proc. potatoes	0.008	–0.001	0.010†	–0.007			
	(0.005)	(0.005)	(0.005)	(0.010)			
Fresh tomatoes	–0.004	0.008	0.002	–0.000	0.004		
	(0.006)	(0.006)	(0.005)	(0.005)	(0.009)		

Proc. tomatoes	–0.000	–0.002	0.013‡	–0.010†	0.001	–0.010	
	(0.006)	(0.006)	(0.005)	(0.005)	(0.006)	(0.009)	
Other fresh	–0.024‡	–0.003	–0.034‡	0.015*	–0.045‡	–0.007	0.015
	(0.007)	(0.007)	(0.007)	(0.008)	(0.008)	(0.007)	(0.013)
Other proc.	–0.002	0.015†	0.032‡	–0.001	–0.004	–0.004	0.011
	(0.007)	(0.007)	(0.007)	(0.008)	(0.007)	(0.007)	(0.011)
Error standard deviations							
σ_i	0.082‡	0.083‡	0.085‡	0.151‡	0.093‡	0.077‡	0.153‡
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.003)
Error correlations (ρ_{ij})							
Proc. dg-dy	–0.162‡						
	(0.029)						
Fresh potatoes	0.141‡	–0.134‡					
	(0.024)	(0.028)					
Proc. potatoes	–0.340‡	–0.025	–0.219‡				
	(0.025)	(0.027)	(0.024)				
Fresh tomatoes	0.011	–0.163‡	0.016	–0.222‡			
	(0.027)	(0.028)	(0.026)	(0.026)			
Proc. tomatoes	–0.108‡	–0.099‡	–0.080‡	–0.093‡	–0.089†		
	(0.025)	(0.027)	(0.028)	(0.025)	(0.027)		
Other fresh	0.314‡	–0.273‡	0.114‡	–0.438‡	0.172‡	–0.117‡	
	(0.023)	(0.025)	(0.027)	(0.022)	(0.025)	(0.027)	
Log-likelihood	8658.614						

Note: Asymptotic standard errors in parentheses. Levels of statistical significance: ‡ = 1%, † = 5%, * = 10%. Parameter estimate for the own-price coefficients for other2 ($\beta_{8,8}$) is –0.037, with a standard error of 0.018.

Table 3. Maximum Simulated Likelihood Estimates of Translog Demand System: High-Income Households

Variables	Fresh dg-dy	Proc. dg-dy	Fresh potatoes	Proc. potatoes	Fresh tomatoes	Proc. tomatoes	Other fresh
Demographic variables (α_{ij})							
Constant	0.034†	–0.027†	0.028†	0.015	–0.023	0.001	0.326‡
	(0.014)	(0.013)	(0.013)	(0.024)	(0.016)	(0.011)	(0.025)
Household size	–0.014‡	0.001	–0.009‡	0.026‡	–0.006*	0.011‡	–0.034‡
	(0.004)	(0.003)	(0.003)	(0.005)	(0.003)	(0.002)	(0.006)
Children ≥ 18	0.013*	0.016‡	–0.012†	0.038‡	–0.020‡	–0.016‡	–0.021*
	(0.007)	(0.006)	(0.006)	(0.011)	(0.008)	(0.005	(0.013)
Female head	0.024‡	–0.009	0.022‡	–0.006	0.015‡	–0.012‡	0.044‡
	(0.006)	(0.006)	(0.005)	(0.010	(0.006)	(0.005)	(0.011
Hispanic	–0.026‡	–0.010	0.002	0.001	0.058‡	0.021‡	–0.035*
	(0.011)	(0.010)	(0.008)	(0.017)	(0.010)	(0.008)	(0.019)
White	–0.047‡	0.016†	–0.001	0.073‡	0.003	0.006	–0.090‡
	(0.009)	(0.008)	(0.008)	(0.017)	(0.011)	(0.008)	(0.016)
Black	–0.055‡	0.073‡	0.003	0.019	–0.026†	0.004	–0.121‡
	(0.010)	(0.010)	(0.010)	(0.020)	(0.013)	(0.009)	(0.020)
East	–0.017†	0.052‡	–0.022‡	0.012	–0.008	0.022‡	–0.062‡
	(0.007)	(0.007)	(0.006)	(0.011)	(0.007)	(0.005)	(0.012)
Central	–0.050‡	0.030‡	–0.013†	0.071‡	–0.024‡	0.010*	–0.103‡
	(0.007)	(0.006)	(0.006)	(0.011)	(0.007)	(0.006)	(0.012)
South	–0.048‡	0.056‡	0.004	0.032‡	–0.014†	0.002	–0.112‡
	(0.007)	(0.007)	(0.005)	(0.011)	(0.007)	(0.005)	(0.012)
Quadratic prices (β_{ij})							
Fresh dg-dy	0.022‡						
	(0.006)						
Proc. dg-dy	–0.004	0.013†					
	(0.004)	(0.006)					
Fresh potatoes	–0.020‡	–0.004	0.014†				
	(0.004)	(0.004)	(0.007)				
Proc. potatoes	–0.008*	0.003	0.009‡	0.006			
	(0.004)	(0.004)	(0.004)	(0.009)			
Fresh tomatoes	–0.014‡	–0.011‡	0.001	0.005	0.036‡		
	(0.005)	(0.004)	(0.005)	(0.004)	(0.008)		

Proc. tomatoes	–0.001	0.001	0.009†	–0.001	–0.006	0.012†	
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	
Other fresh	–0.019‡	–0.028‡	–0.047‡	–0.007	–0.049‡	–0.013‡	0.073‡
	(0.005)	(0.005)	(0.006)	(0.006)	(0.007)	(0.004)	(0.010)
Other proc.	–0.006	0.023‡	0.013‡	0.009	–0.012†	–0.007*	–0.025†
	(0.006)	(0.005)	(0.005)	(0.007)	(0.006)	(0.005)	(0.009)
Error standard deviations							
σ_i	0.087‡	0.075‡	0.077‡	0.142‡	0.090‡	0.068‡	0.151‡
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Error correlations (ρ_{ij})							
Proc. dg-dy	–0.185‡						
	(0.018)						
Fresh potatoes	0.066‡	–0.147‡					
	(0.019)	(0.018)					
Proc. potatoes	–0.333‡	–0.008	–0.188‡				
	(0.017)	(0.017)	(0.016)				
Fresh tomatoes	0.055‡	–0.176‡	0.002	–0.225‡			
	(0.018)	(0.019)	(0.017)	(0.018)			
Proc. tomatoes	–0.113‡	–0.074‡	–0.065‡	–0.078‡	–0.102‡		
	(0.020)	(0.019)	(0.019)	(0.017)	(0.019)		
Other fresh	0.251‡	–0.306‡	0.077‡	–0.418‡	0.120‡	–0.136‡	
	(0.017)	(0.016)	(0.017)	(0.015)	(0.017)	(0.019)	
Log-likelihood	18657.786						

Note: Asymptotic standard errors in parentheses. Levels of statistical significance: ‡ = 1%, † = 5%, * = 10%. Parameter estimate for the own-price coefficients for other2 ($\beta_{8,8}$) is –0.073, with a standard error of 0.011.

Table 4. Price Elasticities: Low-Income Households

	Prices of								
Product	Fresh dg-dy	Proc. dg-dy	Fresh potatoes	Proc. potatoes	Fresh tomatoes	Proc. tomatoes	Other fresh	Other proc.	Total expend.
	Uncompensated Elasticities								
Fresh dg-dy	–0.97‡	–0.01	–0.15‡	0.07	–0.02	0.01	–0.20‡	–0.04	1.32‡
	(0.07)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)	(0.07)	(0.03)
Proc. dg-dy	0.00	–1.24‡	–0.02	–0.02	0.08	–0.01	–0.01	0.11*	1.10‡
	(0.05)	(0.08)	(0.05)	(0.04)	(0.05)	(0.05)	(0.06)	(0.06)	(0.03)
Fresh potatoes	–0.15‡	–0.02	–1.27‡	0.09†	0.03	0.13‡	–0.29‡	0.27‡	1.22‡
	(0.05)	(0.05)	(0.07)	(0.05)	(0.05)	(0.05)	(0.06)	(0.07)	(0.03)
Proc. potatoes	0.05‡	0.00	0.06‡	–1.04‡	0.02	–0.03	0.10‡	–0.05	0.88‡
	(0.02)	(0.02)	(0.02)	(0.04)	(0.02)	(0.02)	(0.03)	(0.03)	(0.02)
Fresh tomatoes	–0.01	0.06	0.02	–0.01	–0.95‡	0.02	–0.29‡	–0.07	1.22‡
	(0.04)	(0.04)	(0.04)	(0.04)	(0.07)	(0.04)	(0.05)	(0.05)	(0.03)
Proc. tomatoes	0.02	–0.01	0.14‡	–0.10†	0.03	–1.09‡	–0.04	–0.07	1.14‡
	(0.06)	(0.05)	(0.05)	(0.05)	(0.06)	(0.08)	(0.07)	(0.06)	(0.03)
Other fresh	–0.04†	0.00	–0.08‡	0.03	–0.10‡	–0.01	–0.91‡	–0.03	1.12‡
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)	(0.03)	(0.01)
Other proc.	0.03†	0.03‡	0.08‡	–0.02	0.04‡	0.01	0.05†	–0.98‡	0.76‡
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.03)	(0.02)

Table 4 (continued)

	Compensated Elasticities							
Fresh dg-dy	–0.90‡	0.06	–0.08*	0.25‡	0.09*	0.08	0.14†	0.37‡
	(0.07)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)
Proc. dg-dy	0.06	–1.18‡	0.04	0.13‡	0.17‡	0.05	0.27‡	0.46‡
	(0.05)	(0.08)	(0.05)	(0.04)	(0.05)	(0.05)	(0.06)	(0.06)
Fresh potatoes	–0.08*	0.04	–1.20‡	0.26‡	0.12‡	0.19‡	0.02	0.65‡
	(0.05)	(0.05)	(0.07)	(0.05)	(0.05)	(0.05)	(0.06)	(0.07)
Proc. potatoes	0.10‡	0.05†	0.10‡	–0.91‡	0.09‡	0.01	0.33‡	0.23‡
	(0.02)	(0.02)	(0.02)	(0.04)	(0.02)	(0.02)	(0.03)	(0.03)
Fresh tomatoes	0.06	0.13‡	0.09‡	0.16‡	–0.86‡	0.08†	0.02	0.32‡
	(0.04)	(0.04)	(0.04)	(0.04)	(0.07)	(0.04)	(0.05)	(0.05)
Proc. tomatoes	0.08	0.05	0.20‡	0.06	0.12†	–1.03‡	0.25‡	0.28‡
	(0.06)	(0.05)	(0.05)	(0.05)	(0.06)	(0.08)	(0.07)	(0.06)
Other fresh	0.02	0.06‡	–0.02	0.19‡	–0.01	0.05‡	–0.62‡	0.32‡
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)	(0.03)
Other proc.	0.07‡	0.07‡	0.12‡	0.09‡	0.10‡	0.05‡	0.24‡	–0.74‡
	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.03)

Note: Asymptotic standard errors in parentheses. Levels of statistical significance: ‡ = 1%, † = 5%, * = 10%.

Table 5. Price Elasticities: High-Income Households

	Prices of								
Product	Fresh dg-dy	Proc. dg-dy	Fresh potatoes	Proc. potatoes	Fresh tomatoes	Proc. tomatoes	Other fresh	Other proc.	Total expend.
	Uncompensated Elasticities								
Fresh dg-dy	–0.83‡	–0.03	–0.13‡	–0.06†	–0.08	0.00	–0.09‡	–0.07†	1.27‡
	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.02)
Proc. dg-dy	–0.02	–0.88‡	–0.02	0.02	–0.08†	0.01	–0.20‡	0.17‡	1.00‡
	(0.03)	(0.05)	(0.03)	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)	(0.02)
Fresh potatoes	–0.14‡	–0.03	–0.88‡	0.06†	0.03	0.07†	–0.33‡	0.08†	1.14‡
	(0.03)	(0.03)	(0.05)	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)	(0.02)
Proc. potatoes	–0.01	0.01	0.05‡	–0.98‡	0.04†	0.00	0.01	0.01	0.87‡
	(0.02)	(0.02)	(0.02)	(0.04)	(0.02)	(0.02)	(0.03)	(0.03)	(0.01)
Fresh tomatoes	–0.06†	–0.06‡	0.02	0.02	–0.76‡	–0.03	–0.24‡	–0.10‡	1.22‡
	(0.03)	(0.03)	(0.03)	(0.03)	(0.05)	(0.03)	(0.04)	(0.03)	(0.02)
Proc. tomatoes	0.01	0.01	0.09‡	–0.02	–0.04	–0.88‡	–0.09‡	–0.09†	1.01‡
	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.05)	(0.04)	(0.04)	(0.01)
Other fresh	–0.01	–0.06‡	–0.09‡	–0.02†	–0.08‡	–0.02‡	–0.77‡	–0.10‡	1.15‡
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)
Other proc.	0.02†	0.06‡	0.06‡	0.01	0.02†	0.00	–0.02	–0.89‡	0.74‡
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)

Table 5 (continued)

	Compensated Elasticities							
Fresh dg-dy	–0.74‡	0.04	–0.05*	0.08‡	0.03	0.06†	0.28‡	0.29‡
	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)
Proc. dg-dy	0.05	–0.83‡	0.04	0.13‡	0.01	0.06*	0.09*	0.46‡
	(0.03)	(0.05)	(0.03)	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)
Fresh potatoes	–0.06*	0.03	–0.81‡	0.19‡	0.13‡	0.12‡	–0.01	0.40‡
	(0.03)	(0.03)	(0.05)	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)
Proc. potatoes	0.05‡	0.06‡	0.10‡	–0.88‡	0.12‡	0.04‡	0.26‡	0.26‡
	(0.02)	(0.02)	(0.02)	(0.04)	(0.02)	(0.02)	(0.03)	(0.03)
Fresh tomatoes	0.02	0.00	0.09‡	0.16‡	–0.65‡	0.02	0.11‡	0.25‡
	(0.03)	(0.03)	(0.03)	(0.03)	(0.05)	(0.03)	(0.04)	(0.03)
Proc. tomatoes	0.08†	0.07*	0.15‡	0.10‡	0.05	–0.84‡	0.20‡	0.20‡
	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.05)	(0.04)	(0.04)
Other fresh	0.07‡	0.00	–0.02†	0.10‡	0.02*	0.03‡	–0.44‡	0.23‡
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
Other proc.	0.08‡	0.10‡	0.10‡	0.09‡	0.09‡	0.03‡	0.19‡	–0.68‡
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)

Note: Asymptotic standard errors in parentheses. Levels of statistical significance: ‡ = 1%, † = 5%, * = 10%.