Modeling Fresh Organic Produce Consumption With Scanner Data: A Generalized Double Hurdle Model Approach

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ABSTRACT

Previous studies using consumer surveys based on contingent valuations gave inconsistent or even contradictory results with respect to the impact of some consumer characteristics on organic foods consumption. Using actual retail-level data, this study provides an objective view of the consumers' social economic characteristics related to the growth of the fresh organic produce market with a generalized double hurdle model. Market participation and conditional/unconditional consumption elasticities were computed for the generalized double hurdle model. [EconLit citations: C240, D120, Q110]. © 2008 Wiley Periodicals, Inc.

1. INTRODUCTION

Concerns over health and environmental degradation have motivated U.S. consumers to purchase more organic produce in recent years. U.S. sales of organic foods were nearly \$10.4 billion in 2003, or about 1.8% of total U.S. retail food sales, up from \$3.5 billion in 1997 (Nutrition Business Journal, 2004). In response to the growing popularity of organic items, conventional supermarkets and mass-market merchandisers have added shelf space for organic fruits and vegetables. In 2000, for the first time, more organic food was purchased in conventional supermarkets than in any other venue (Dimitri & Greene, 2002).

Among various organic foods, fresh fruits and vegetables have much higher market-penetration rates than do others. For example, in 2002, organic fresh fruit and vegetable sales accounted for 4.5% of total fresh fruit and vegetable sales (Nutrition Business Journal, 2003). The *Natural Foods Merchandiser* reported that sales of packaged fresh produce in natural foods supermarkets had the highest growth rate among sales of all organic products during 2003 to 2004, expanding 35.4% annually on average to \$171.9 million.

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Despite the projected high growth in consumption of fresh organic produce, consumer characteristics contributing to its growth are not well understood. Most previous studies of organic produce have measured attitudes regarding the purchase of organic produce rather than actual purchase choices or behaviors (Huang, 1996; Jolly, 1991; Williams & Hammitt, 2000). As an indication of such attitudes, these studies typically have elicited willingness to pay for organic produce and the likelihood of consumption relative to conventional counterparts. Additionally, results from previous studies using surveys often have been fragmentary and sometimes inconsistent. Thompson (1998) summarized studies prior to 1997 regarding the impact of demographic characteristics on the likelihood of consumption of organic foods. His study revealed some contradictory findings about the effects of income, age, and educational attainment on likelihood of consuming organic foods. More recent survey studies also had different conclusions regarding the impact of income on consumption of organic food. A survey conducted by the Hartman Group in 2002 showed that over half of those who frequently buy organic foods in the United States have incomes below $30,000 and that African Americans, Asian Americans, and Hispanics use more organic products than do Caucasians. Results of the Hartman Group survey are interesting, given that a USDA–ERS study found that low-income households eat less fresh fruits and vegetables than do higher income households (Blisard, Stewart, & Jolliffe, 2004). Thus, additional research on who buys organic foods is needed (Oberholtzer, Dimitri, & Greene, 2005).

Our objective in this study is to identify important consumer-demographic characteristics that are associated with fresh organic produce consumption and investigate their effects on consumption. To achieve this purpose, we utilize a generalized double hurdle model which allows for different parameterizations of the participation and consumption processes and the possible correlation between these two processes.

2. MODEL SPECIFICATION

For most cross-sectional consumption data, zero consumption is a problem for any modeling effort to address. The tobit model developed by Tobin (1958) has been widely used to deal with censored observations. It attributes the censoring to a standard corner solution. However, this model is very restrictive. For example, the tobit model has been shown to be inadequate to characterize the two processes in consumption: the participation process and the consumption process. Any variable which increases the probability of nonzero consumption also must increase the mean of positive consumption, which is not always reasonable (Lin & Schmidt, 1984). Even though the impacts of explanatory variables on the probability of consumption and level of consumption may be in the same direction, the magnitudes and statistical significance levels for these two processes could be quite different. For example, advertising intended to solicit memberships may not be effective in increasing revenue. The tobit model is not flexible enough to accommodate all these outcomes.[1]

[1]As one of the reviewers noted, the marginal impacts of a variable change on the components of probability of purchase and the level of purchase will differ in magnitude and significance even though the coefficients on the variables were constrained to be the same under the tobit model; however, by relaxing the restriction imposed implicitly under the tobit model, greater flexibilities can be achieved with respect to directional change, the size and significance of the variables included in the model with respect to the probability, and the level of consumption.

The double hurdle model, originally proposed by Cragg (1971), assumes that households make two decisions with respect to purchasing an item, each of which is determined by a different set of explanatory variables. To observe a positive level of expenditure, two separate hurdles must be passed. First, the household decides whether to purchase the good. Second, by overcoming inhibition factors in acquisition such as search, information, and transaction costs, the household determines what it wants and decides on how much to purchase. A different latent variable is used to model each decision process, with one part modeling discrete choice of whether to purchase organic with a specification similar to that of a probit model and the other part modeling the positive amount of purchase using a specification similar to a censored regression. The double hurdle model has been used widely since its introduction. Dong, Chung, and Kaiser (2004) used it to model milk-purchasing behavior with panel data. Newman, Henchion, and Matthews (2003) applied the double hurdle model to study Irish household expenditures on prepared meals for home consumption. Yen and Jones (1997) used the procedure for analysis of U.S. household consumption of cheese. Other studies also have applied the double hurdle model to examine U.S. food expenditures away from home (Jensen & Yen, 1996) and household demand for finfish (Yen & Huang, 1996). Most applications rejected the tobit model in favor of Cragg's independent double hurdle model based on statistical tests.

Though Cragg's model is an improvement over the tobit model, it is still limited in that it assumes that the shocks to the participation and consumption processes are independent, which is not always a realistic assumption. Hidden factors that inhibit potential organic consumers from making actual purchases, such as availability, may result in consumers being excluded from the organic market in the first place. Drawing on the idea of correlated processes from the sample selection model of Heckman (1979), the generalized double hurdle model extended Cragg's independent double hurdle model to deal with correlated residuals from the participation and consumption processes. Jones (1989, 1992) first used the generalized double hurdle model in analyzing tobacco consumption in the United Kingdom. Similarly, Yen (2005) applied the generalized approach to study cigarette consumption in the United States and concluded that the hypothesis of equal consumption parameters should be rejected. The specification of the generalized double hurdle model is as follows:

$$y = \begin{cases} x'\beta + v & \text{if } z'\alpha + u > 0 \text{ and } x'\beta + v > 0 \\ 0 & \text{otherwise} \end{cases}$$
$$\begin{bmatrix} u \\ v \end{bmatrix} = N\left\{0, \begin{bmatrix} 1 & \rho\sigma \\ \rho\sigma & \sigma^2 \end{bmatrix}\right\}, \tag{1}$$

where y is the expenditure, in original or transformed scale if applicable; z and x are variables determining the participation and the consumption processes, respectively; u and v are residual terms from the two processes, with a correlation coefficient ρ; and α, β, ρ, and σ are parameters for estimation.

The likelihood function can be represented as:

$$L = \prod_{y=0} \{1 - \Psi(z'\alpha, x'\beta/\sigma; \rho)\} \times \prod_{y>0} \frac{1}{\sigma}\phi[(y - x'\beta)/\sigma]\Phi\left[\frac{z'\alpha + \rho(y - x'\beta)/\sigma}{(a - \rho^2)^{1/2}}\right], \tag{2}$$

where $\phi(\cdot)$ is the univariate standard normal probability density function (PDF) and $\Phi(\cdot)$ is the conditional standard normal cumulative distribution function (CDF) for u given $v = y - x'\beta$,[2] and $\Psi(\cdot)$ is the bivariate standard normal CDF. It represents the probability when both hurdles are cleared and a positive purchase is observed. When $\rho = 0$, the previous model reduces to Cragg's (1971, Equations 5 and 6) independent double hurdle model. In this analysis, we use one set of explanatory variables for both processes, $x = z$, as these variables represent all of the relevant demographic information available in the data which may be related to both processes.

3. DATA AND VARIABLES

Nielsen Homescan for 2003 is the data source of this study. Nielsen Homescan is unique in that each panelist was supplied with a scanner device that he or she used at home to record grocery items purchased at any grocery or other type of store throughout a given time period. Each panelist represents a unique household, with each household having 18 known demographic characteristics. By investigating the relationship between consumption of fresh organic produce and consumer characteristics, we can identify potential consumers of fresh organic produce.

In 2003, there were 8,833 households included in the Nielsen consumer panel. The date, expenditure, and quantity of each purchase are recorded with the supplied scanner. To avoid the potential data problem of inadvertent recording by some households, we included only those households who made purchases of fresh produce for at least 10 months in 2003, which reduced the sample to 6,916 households. Total expenditures for organic fresh produce in 2003 were aggregated for each household, resulting in a final cross-sectional dataset containing organic expenditures and corresponding consumer demographic characteristics as described in Table 1.

The positive organic expenditure is specified via the following equation:

$$\begin{aligned}\ln C =& \beta_0 + \beta_1 \,\mathrm{HHSIZE} + \beta_2 \,\mathrm{INCOME} + \beta_3 \,\mathrm{AGE\,2} \\ &+ \beta_4 \,\mathrm{AGE\,3} + \beta_5 \,\mathrm{EDUC\,2} + \beta_6 \,\mathrm{EDUC\,3} \\ &+ \beta_7 \,\mathrm{CHILD\,6} + \beta_8 \,\mathrm{EAST} + \beta_9 \,\mathrm{CENTRAL} \\ &+ \beta_{10} \,\mathrm{WEST} + \beta_{11} \,\mathrm{URBAN} + \beta_{12} \,\mathrm{WHITE} \\ &+ \beta_{13} \,\mathrm{BLACK} + \beta_{14} \,\mathrm{ORIENTAL}. \end{aligned} \tag{3}$$

This functional form is applied for the consumption process expressed in Equation 1. The natural logarithm of the positive expenditure of fresh organic produce is modeled as a function of various consumer-demographic variables. For zero expenditures, the dependent variable, y, still takes on the value of zero to model the participation process.[3]

[2]See Johnson and Kotz (1970) for the derivation of the conditional standard normal CDF, or the conditional probability that $z'\beta + u > 0$ given $v = y - x'\beta$.

[3]Since the expenditure is in cents, all greater than 1 in magnitude for organic foods purchases, the natural logarithmic of the positive expenditure remains positive. Zero expenditure, without transformation, will stay as the truncated part. This ensures that zero and positive expenditures neatly fall into the participation and consumption parts of the maximum likelihood function.

TABLE 1. Definition of Variables and Sample Statistics

Variables	Definition	*M* (*SE*)
ORGCOST (*C*) ash; full sample	Per household expenditure on organic fresh produce (full sample)	$6.51 (29.60)
ORGCOST (*C*)-organic buyers	Per household expenditure on organic fresh produce (organic buyers)	$15.33 (43.89)
HHSIZE	Household size–No. of people in a household	2.47 (1.34)
INCOME	Income ($1000), midpoint of income category	52.87 (27.36)
Dummy variables (Yes = 1, No = 0)		
AGE1	The higher age of the male and female household heads is less than 40	0.13
AGE2	The higher age of the male and female household heads is between 40 and 64	0.61
AGE3	The higher age of the male and female household heads is 65 and above	0.26
EDUC1	The higher education of the male and female household heads is high school	0.18
EDUC2	The higher education of the male and female household heads is college	0.65
EDUC3	The higher education of the male and female household heads is post college	0.17
CHILD6	Households with children under 6 years old	0.09
EAST	Residents in East region	0.21
CENTRAL	Residents in Central region	0.19
SOUTH	Residents in South region	0.39
WEST	Residents in West region	0.21
URBAN	Residents in urban areas	0.87
RURAL	Residents in rural areas	0.13
WHITE	White households	0.76
BLACK	Black households	0.11
HISPANIC	Hispanic households	0.08
OTHER	Households of other races	0.04
Sample size		6,916

Source: Compiled from the 2003 Nielsen Homescan data.

As shown in Table 1, the average amount of organic produce purchases for all households was $6.51 in 2003. Among all households on the panel, about 42% actually purchased fresh organic produce with the average level of expenditure at $15.33. A problem with the fresh organic produce expenditure variable is that the distribution of the values is highly skewed, with most consumers spending small amounts on organic as shown in Figure 1. This is a common problem with consumption data, as was the case for U.S. consumption of cheese (Yen & Jones, 1997) and finfish (Yen & Huang, 1996). However, for econometric models, whether double hurdle, tobit, or Ordinary Least Squares, they are valid only under the assumption that the normal distribution (or censored normal distribution) of the dependent variable is satisfied. If used directly as a response variable without

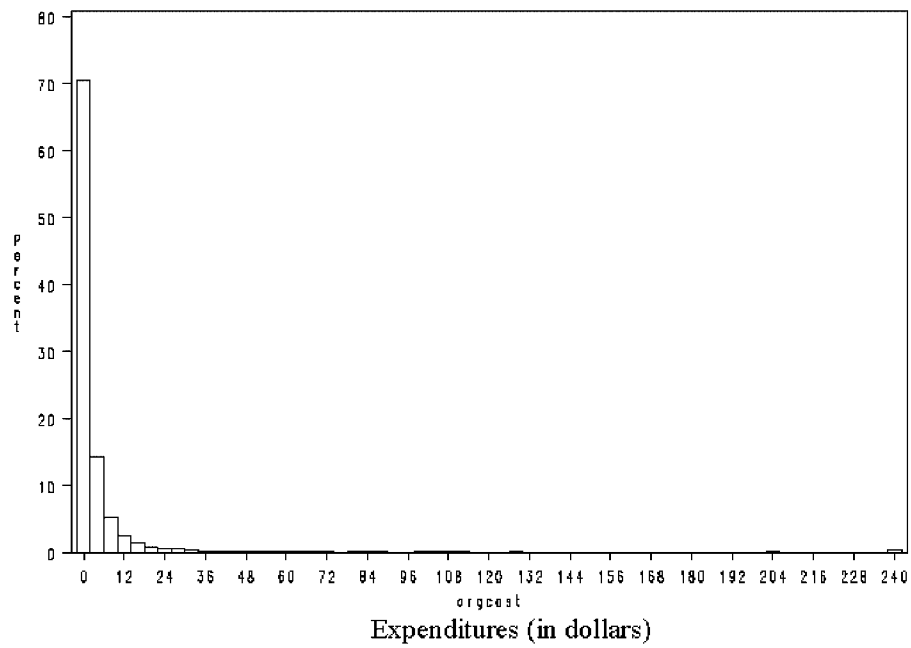

Figure 1 Distribution of Fresh Organic Produce Expenditures in Original Scale.

transformation, consumption data may cause inconsistency of the estimators and nonnormality of the error terms (Newman et al., 2003). In this study, following Wagner and Hanna (1983) and Newhouse (1987), we used the natural logarithm of positive fresh organic produce consumption to be able to handle positively skewed data.[4] Figure 2 shows the histograms of transformed positive expenditures, which suggest that the natural logarithm of consumption is more likely to be normally distributed. In addition, the natural logarithmic transformation of the response variable is more amenable to computing elasticities of organic consumption with respect to demographic variables than are other nonlinear transformations.

4. ELASTICITIES

Elasticities of consumption probability and level (conditional and unconditional for the latter) are computed using Yen's (2005) formula. The probability of consumption (i.e., a positive observation) is:

$$\Pr(y > 0) = \Psi(z'\alpha, x'\beta/\sigma; \rho), \tag{4}$$

[4]How to handle the problem of nonnormal distributions is a matter of choice. Yen (1993) chose the Box-Cox transformation approach that allows for skewness in the dependent variable and specifies the transformed variable as truncated normal. The more direct approach of log-normal transformation used in this study also was suggested by Cragg (1971) and Amemiya and Boskin (1974).

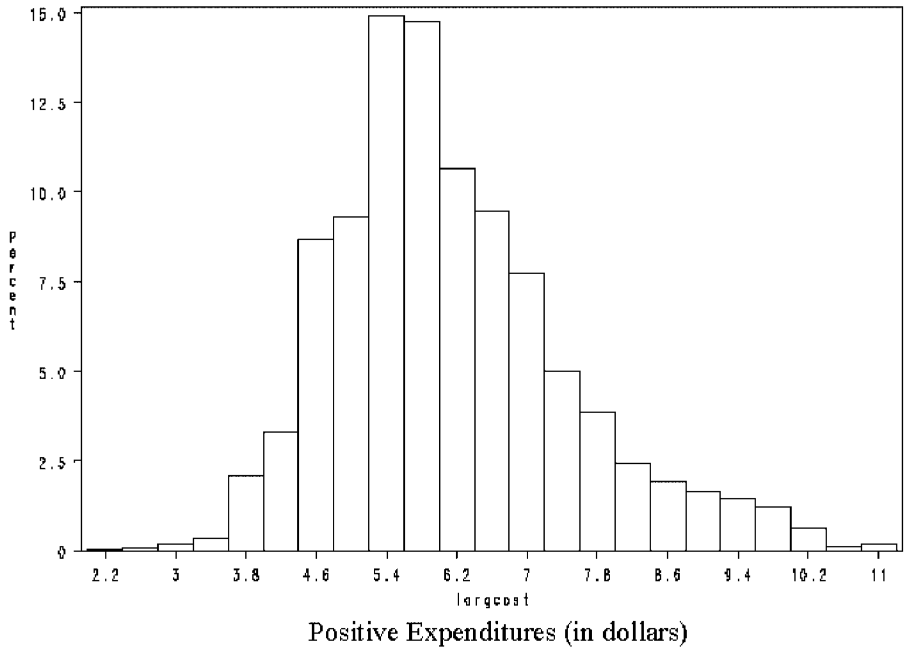

Figure 2 Distribution of Fresh Organic Produce Expenditures in Natural Logarithm Scale.

which depends on both participation and consumption process parameters. The conditional and unconditional means of the dependent variable are given as follows:

$$\begin{aligned} E(y|y>0) &= x'\beta + E(v/u> -z'\alpha, v> -x'\beta) \\ &= x'\beta + [\Psi(zz'\alpha, x'\beta/\sigma, \rho)]^{-1}\sigma \\ &\quad \times \{\phi(x'\beta/\sigma)\Phi[(z'\alpha - \rho x'\beta/\sigma)/(1-\rho^2)^{1/2}] \\ &\quad + \rho\phi(z'\alpha)\Phi[(x'\beta/\sigma - \rho z'\alpha)/(1-\rho^2)^{1/2}]\}, \end{aligned} \tag{5}$$

and

$$E(y) = \Pr(y>0) \times E(y|y>0). \tag{6}$$

As the dependent variable is in natural logarithmic form for positive expenditures, the conditional and unconditional elasticities with respect to consumption level can be computed as $(\partial E(y|y>0)/\partial x) \times \bar{x}$ and $(\partial E(y)/\partial x) \times \bar{x}$, respectively, for continuous variables, $\Delta E(y|y>0)$ and $\delta E(y)$ for discrete variables. Elasticities with respect to market participation probability were computed as $\partial P(y>0)/\partial x) \times (\bar{x}/\bar{P})$ for continuous variables. However, for discrete variables, marginal effects with respect to market participation probabilities $[\delta P(y>0)]$ were reported since they are more meaningful in interpretation. Elasticities and marginal effects are evaluated for each explanatory variable with all other variables held constant at mean levels. Standard errors of our elasticities estimates were calculated by first-order mathematical approximation (Davidson & Mackinnon, 2004), more commonly known as the *delta method*.

5. ESTIMATION RESULTS

Results of the maximum likelihood estimation for the generalized double hurdle model are presented in Table 2. The correlation coefficient between residuals from the market participation and consumption processes is 0.8994 and highly significant, indicating that the generalized double hurdle model is preferred to Cragg's (1971) independent double hurdle model in this study. Based on Equations 4 to 6, the marginal probability effects (for discrete variables only) and conditional and unconditional elasticities for all demographic variables were calculated and reported in Table 3.

Among consumer-demographic variables, household income has a positive and significant effect for both processes. Higher income is associated with both a higher probability and a higher level of fresh organic produce consumption. The unconditional income elasticity of consumption is about 0.37, which means an average household will increase organic fresh produce expenditures by 0.37% when household income rises by 1%. For organic buyers, however, a 1% increase in income will result in a 0.22% increase in organic expenditures on average.

The effect of household size suggests that the larger the household, the less likely is the consumption of fresh organic produce. Further, for current organic buyers, larger households do not necessarily spend more on fresh organic produce. The overall impact of household size on consumption of fresh organic produce, as indicated by the small and insignificant unconditional elasticity with respect to consumption level, is negligible.

The role of the age of household head on expenditures for fresh organic produce is mixed with respect to market participation and consumption decisions. As shown in the results, among the three age groups, the older group was found to be significantly more likely to buy fresh organic produce. Of households that buy organic, those with older household heads spend less than those with younger ones. Overall, older consumers are important patrons of the fresh organic market, spending 28% more than do younger ones, holding other factors equal. Educational level is highly significant in explaining both market participation and consumption of fresh organic produce. The results seem to suggest that the higher the educational level of the household head, the more likely the household is to buy fresh organic produce. Of the households that are organic buyers, higher educational level of the household head also is associated with a higher level of consumption. Among all dummy variables, the postcollege degree (EDUC3) has the highest probability marginal effect and conditional elasticity with respect to both market participation and level of expenditure. For an average household with the household head having a postcollege degree, the household is 12% more likely to consume fresh organic produce and spends about 87% more on organic than an average household with the household head having only a high-school education, ceteris paribus.

The binary effects also show that in 2003, ceteris paribus, urban households spent about 40% more on fresh organic produce than did rural households. The main reason for this is that urban households are 6% more likely to be organic buyers than are rural households. There was no significant difference between organic buyers regarding expenditures. A dummy variable for households with one or more children under 6 years of age was included in the model to measure the possible impact of parental concern for the health of young children on organic expenditures;

TABLE 2. Maximum Likelihood Estimates of the Generalized Double Hurdle Model

	Participation Process	Consumption Process
	Parameters (*SE*)	Parameters(*SE*)
CONSTANT	−.7028**	3.8712**
	(.0802)	(0.1524)
HHSIZE	−0.0215*	−0.0099
	(0.0131)	(0.0237)
INCOME	0.0022**	0.0042**
	(0.0006)	(0.0011)
AGE2	0.0475	−0.1414
	(0.0490)	0.0882
AGE3	0.1647**	−0.0760
	(0.0559)	(0.1002)
EDUC2	0.1519**	0.2712**
	(0.0414)	(0.0761)
EDUC3	0.3031**	0.6528**
	(0.0548)	(0.0988)
CHILD6	−0.0240	−0.0660
	(0.0630)	(0.1129)
EAST	0.2111**	0.4036**
	(0.0403)	(0.0717)
CENTRAL	−0.0404	−0.0395
	(0.0431)	(0.0793)
WEST	0.1680**	0.4067**
	(0.0403)	(0.0718)
URBAN	0.1671**	0.2005**
	(0.0462)	(0.0856)
BLACK	0.0326	0.1240
	(0.0479)	(0.0871)
HISPANIC	0.3030**	0.3576**
	(0.0562)	(0.0976)
OTHER	0.2380**	0.4467**
	(0.0737)	(0.1273)
σ		1.7742**
		(0.0254)
ρ		0.8994**
		(0.0100)
Log Likelihood Value	−6,825.0	
Likelihood Ratio $\chi^2(p)$	<0.001	

Note. Double asterisks and single asterisk denote significance at 5 and 10%, respectively.

however, this variable was not significant in determining the likelihood of fresh organic purchases or level of consumption. This may be due to the many substitute organic foods available for children, such as baby foods and diary products.

Results for the U.S. geographic dummy variables indicate that the households with the highest to lowest probability and level of fresh organic produce consumption are in the East, followed by the West, then the South, and finally the Central states. The census regions are as indicated by Nielsen (2006). These results echo the fact that the

TABLE 3. Marginal Effects and Elasticities of Demographic Variables

Variable	Probability elasticity[a]/Marginal effect[b]	Conditional level elasticity	Unconditional levelelasticity
Continuous variable			
INCOME	0.1036**	0.2194**	0.3684**
	(0.0302)	(0.0595)	(0.0977)
Discrete variable			
HHSIZE	−0.0085*	0.0132	−0.0458
	(0.0051)	(0.0186)	(0.0325)
AGE2	0.0185	−0.1931**	0.0343
	(0.0190)	(0.0678)	(0.1230)
AGE3	0.0648**	−0.2519**	0.2880**
	(0.0219)	(0.0773)	(0.1408)
EDUC2	0.0588**	0.1049*	0.3965**
	(0.0158)	(0.0588)	(0.0984)
EDUC3	0.1188**	0.3285**	0.8712**
	(0.0214)	(0.0767)	(0.1371)
CHILD6	−0.0094	−0.0402	−0.0745
	(0.0247)	(0.0862)	(0.1561)
EAST	0.0833**	0.1798**	0.5877**
	(0.0159)	(0.0552)	(0.1022)
CENTRAL	−0.0156	0.0050	−0.0916
	(0.0166)	(0.0612)	(0.1036)
WEST	0.0661**	0.2273**	0.5041**
	(0.0159)	(0.0555)	(0.1022)
URBAN	0.0649**	0.0182	0.4020**
	(0.0176)	(0.0665)	(0.1112)
BLACK	0.0128	0.0888	0.1159
	(0.0188)	(0.0675)	(0.1207)
HISPANIC	0.1203**	0.0443	0.7535**
	(0.0223)	(0.0754)	(0.1450)
OTHER	0.0944**	0.1979**	0.6741**
	(0.0293)	(0.0993)	(0.1931)

Note. Double asterisk and single asterisk denote significance at 5 and 10%, respectively.
*SE*s are in parentheses.
[a]Probability elasticity is used for continuous variables and interpreted as the percentage change in market participation probability in response to the percentage change in the continuous variable.
[b]Probability marginal effect is reported for discrete variables and denotes absolute change in market participation probability in response to one level increase for the multilevel discrete variable (household size) or 0/1 change for the dummy variable.

East has the highest percentage of certified organic acreage and the western area of the United States has the highest level of organic produce production. The certified organic acreage accounted for over 10% of the vegetable acreage in Vermont, New Hampshire, Maine, and Colorado in 2001 (Oberholtzer et al., 2005) while California was the largest organic vegetable producer in 2001, accounting for 41% of U.S. certified organic vegetable acreage. Therefore, people in both the East and West perhaps have broader access to or are more aware of fresh organic produce than are people in other areas.

Among people of different ethnicities, Hispanics, as a group, are more likely to consume fresh organic produce than are those in non-Hispanic White households, the baseline group. The same is true for OTHER households (mostly Asians). In addition, among organic buyers, households of other ethnicities consume significantly higher levels of fresh organic produce than do any other group on average. Overall, Hispanic households and households of other ethnicities are the most likely buyers of fresh organic produce. The probability and level of consumption for Black households are higher, but not significantly different, than those for White households. Thus, the results suggest that minority households may be heavier consumers than White households, all else being equal. These results are consistent with those reported by the Hartman Group (2002) that African Americans, Asian Americans, and Hispanics use more organic products than Caucasians.

6. CONCLUSION

Previous studies from consumer surveys based on contingent valuation have given inconsistent or even contradictory results regarding the impact of certain consumer characteristics on organic food consumption. Using actual retail data, this study provides a more objective view of consumer characteristics that contribute to the viability of the fresh organic produce market.

By estimating the likelihood of market participation and estimating consumption levels simultaneously using maximum likelihood estimation procedure, the generalized double hurdle model distinguishes possible differential impacts of consumer demographic characteristics on organic consumption decisions. Consumption data in natural logarithm form were used in the model to avoid problems such as nonnormally distributed residuals.

The estimated results indicate that marketing strategies targeting higher income and higher educated consumers can be effective in both attracting new consumers and eliciting more sales from current consumers. Age of the household head has mixed effects regarding decisions for organic market participation and consumption levels. The results suggest that minority households are an important segment of the fresh organic produce market which retailers can target effectively.

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