Household Food Purchase Patterns: The Case of Vegetables

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A household's purchase pattern for food can be described along three dimensions: how much food is bought, what types of food are bought, and how often food is bought. All three facets of a household's purchase behavior are potentially important to policymakers and marketers alike, though they have not been studied in a simultaneous framework. The marked purchase renewal model of Boizot et al (2001), for example, has been used to predict how often a household makes a purchase. However, researchers have not considered whether a household's frequency of purchase influences how much food is bought on any shopping occasion. It may be the case that, the more time has elapsed between purchases, the greater the quantity of product a household will purchases on its next shopping occasion.

We propose a model in which all three facets of a household's purchase behavior are simultaneously determined. This model may be further developed and used to simulate the effects of policies and promotions by marketers on household behavior. For illustrative purposes, we consider how different policies are likely to affect the quantity, quality, and frequency of a household's vegetable purchases.

Our model of a household's purchase behavior includes three simultaneous equations. The first models the quality of a household's purchases. As in Dong and Kaiser (2005), among other recent studies, quality is represented by the unit value paid. The second equation uses the model of Boizot et al (2001) to model a household's frequency of purchase. However, our model improves on the approach of Boizot et al (2001) by explicitly incorporating the inter-purchase time effect into our third and final equation of the quantity bought.

Data from Nielsen's 2004 Homescan panel are used for estimation. Participating households report their purchases of food for at-home consumption. The information includes the date of their purchases, total expenditures, food quantities, promotion information, product descriptions, and more. Household characteristic variables are also provided. Recently, these data and alike have been widely used in analyzing the effects of marketing and household variables on a household's food choices (e.g., Kuchler et al, 2005).

How much food is bought, what types of food are bought, and how often food is bought are all potentially important facets of a household's purchase behavior. For example, policymakers may consider using income subsidies or coupon to promote vegetable consumption. Key to selecting the best policy would be evaluating how different policies are likely to affect the quantity of a household's purchases. However, Federal dietary guidance also encourages households to select a variety of vegetables. Buying a larger basket of vegetables that includes only one or two lowest-cost foods is not necessarily healthier than purchasing a slightly smaller, but more varied basket. Also important to selecting the best policy may be how policies influence a household's purchase frequency. Supermarkets serving lower-income households may experience fluctuations in demand that correspond roughly to the time of the month when food assistance benefits are issued.

If so, these supermarkets may also have higher costs for managing inventory and pass higher costs on to households in the form of higher food prices.

Model Household Purchase Behavior

Panel data from household purchase surveys, such as Nielsen's Homescan panel, provide information on purchases of detailed food items by a select household panel over time. Purchase quantity and expenditure for food items are collected at purchase occasions. A certain food category, say vegetables, is purchased in different forms (dried, canned, fresh, etc.) and in different types (corn, lettuce, potato, etc.). A composite food commodity (vegetables) aggregated from individual items (canned corn, fresh lettuce, etc.) is usually used for demand analysis.

Though panel data provide information on the quality, quantity, and frequency of purchases, there remains the problem of dealing with zero purchase observations. The traditional censored model originated by Tobin (1958) and later developed by Heckman (1979) focuses on each possible purchase occasion spot, say every week, and observes the purchase quantity if the household purchased or calculates the probability of a zero purchase if the household did not buy the food in question. Using this approach with panel data involves the missing unit values for non-purchase occasions and the evaluation of multivariate probabilities to account for temporal linkage caused by household heterogeneous effects and others (Dong and Kaiser, 2007).

Unlike the traditional approach, we propose a model that takes only the purchase spot and focuses on the time or the duration between two consecutive purchase occasions. Our model therefore uses only positive observations for unit value and quantity. And it is likewise much easier to estimate. Even more importantly, it answers the question of when to purchase and reveals household purchase patterns over time.

Suppose household *i* identified by its characteristic variable vector X_i purchased quantity Q_{it} of a composite commodity *j* at purchase occasion *t* and had total expenditures of E_{it}. The unit value paid by household *i* at occasion *t* can be obtained as $V_{it} = E_{it} / Q_{it}$. The inter-purchase time between the current purchase occasion *t* and the previous purchase occasion *t*-1 is D_{it}. These variables together answer the questions of what to purchase, how much to purchase, and how often to purchase.

As pointed out by Deaton, the derived unit value (V_{it}) consists of two parts: the exogenous market price and the endogenous commodity quality. The quality part is determined by the purchase choice over different items made by household *i* under the same commodity category. Previous studies (Deaton, 1988,1987,1990; Nelson; Dong et al., Cox and Wohlgenant) show that the unobserved quality choice by household *i* can be partly revealed by its characteristic variable X_i. Accordingly, we define the unit value as:

(1) $$V_{it} = X_i \beta_1 + Z_t \beta_2 + u_i + e_{it}$$

where Z_t is a vector of variables that vary over time (e.g., seasonality) and influence price, u_i is a random effect that captures the impact of household heterogeneity on V_{it}, and e_{it} is an error term.

Equation (1) is an unbalanced panel data model with a random effect. The purchase pattern of each household is different. That is, the number of purchases within the data period or the duration of time between two consecutive purchases (inter-purchase time) varies across households.

The inter-purchase time is a random variable that follows a certain probability distribution. The distribution of inter-purchase times in a market captures the effect of the time elapsed since the last purchase on the timing of the next purchase. This distribution, in general, is also influenced by marketing variables and household characteristics. We assume the distribution of inter-purchase time is exponential. Other forms of the distribution can be found in Kiefer (1988) or Jain and Vilcassim (1991). The exponential pdf of D_{it} is given as:

(2) $$f(D_{it}) = \lambda_{it}\ e^{-\lambda_{it} D_{it}}, \quad \lambda_{it} > 0$$

where λ_{it} is parameter and the expected value of D_{it} is $1/\lambda_{it}$. We introduce the effects of marketing variables and household characteristics through the parameterization of λ_{it} as below:

(3) $$\lambda_{it} = e^{X_i \gamma_1 + W_{it} \gamma_2 + V_{it} \gamma_3}$$

where γ's are parameters to be estimated and W_{it} is a vector of marketing variables faced by household *i* at time *t*. W_{it} includes coupons or other promotions but the unit value V_{it} is separated from these variables for explanatory purposes. The use of the exponential form in (3) is to guarantee λ_{it} being positive. λ_{it} varies across households and also over time, which captures the effects of both household characteristic and marketing variables (seasonality, price, and promotion).

Finally, the purchase quantity made by household i at time t is defined as

(4) $$Q_{it} = X_i\alpha_1 + Z_t\alpha_2 + W_{it}\alpha_3 + V_{it}\alpha_4 + D_{it}\alpha_5 + v_i + \varepsilon_{it}$$

where α's are parameters. Like u_i in (1), v_i is a random effect and ε_{it} is an error term. All other variables are the same as before. Equation (4) implies that the purchase quantity is determined by not only the demographic (X) and social economic variables (Z, W, and V), but by the inter-purchase time (D) as well. We expect a positive relationship between D_{it} and Q_{it}. The longer the inter-purchase time, the more the purchase quantity.

As was mentioned before, the purchase behavior of a given household (X_i) in a given market (Z_t and W_{it}) can be captured by the above equations. For a given food category, say vegetables, equation (1) answers the question of what type vegetable to buy (quality), equation (2) answers the question when to buy (frequency), and equation (4) answers how much to buy.

A maximum likelihood estimator can be adopted to obtain parameter estimates of the above model. We assume e_{it} in (1) and ε_{it} in (4) are identically and independently distributed (iid) normal with mean 0 and variance σ_e^2 and σ_ε^2 respectively, and u_i and v_i are normal with mean 0 and variance σ_u^2 and σ_v^2 respectively. All the error terms are assumed independent from each other and the random variable D_{it} is also independent from all the other error terms. The likelihood function for household i can be written as:

(5) $$L_i = f(\omega_i) f(D_i) f(\psi_i) = (2\pi)^{-\frac{T_i}{2}} |\Sigma|^{-\frac{1}{2}} e^{-\frac{1}{2}\omega_i'\Sigma^{-1}\omega_i} \lambda_i e^{-\lambda_i D_i} (2\pi)^{-\frac{T_i}{2}} |\Omega|^{-\frac{1}{2}} e^{-\frac{1}{2}\psi_i'\Omega^{-1}\psi_i}$$

where $\omega_i = \begin{pmatrix} u_i + e_{i1} \\ u_i + e_{i2} \\ \vdots \\ u_i + e_{iT_i} \end{pmatrix}' = \begin{pmatrix} V_{i1} - X_i\beta_1 - Z_1\beta_2 \\ V_{i2} - X_i\beta_1 - Z_2\beta_2 \\ \vdots \\ V_{iT_i} - X_i\beta_1 - Z_{T_i}\beta_2 \end{pmatrix}'$, $D_i = (D_{i1}, D_{i2}, \cdots, D_{iT_i})$, $\lambda_i = (\lambda_{i1}, \lambda_{i2}, \cdots, \lambda_{iT_i})$,

and $\psi_i = \begin{pmatrix} v_i + \varepsilon_{i1} \\ v_i + \varepsilon_{i2} \\ \vdots \\ v_i + \varepsilon_{iT_i} \end{pmatrix}' = \begin{pmatrix} Q_{i1} - X_i\alpha_1 - Z_{i1}\alpha_2 - W_{i1}\alpha_3 - V_{i1}\alpha_4 - D_{i1}\alpha_5 \\ Q_{i2} - X_i\alpha_1 - Z_{i2}\alpha_2 - W_{i2}\alpha_3 - V_{i2}\alpha_4 - D_{i2}\alpha_5 \\ \vdots \\ Q_{iT_i} - X_i\alpha_1 - Z_{iT_i}\alpha_2 - W_{iT_i}\alpha_3 - V_{iT_i}\alpha_4 - D_{iT_i}\alpha_5 \end{pmatrix}'$. T_i is the total number of purchases made by household *i*. The random effect error components variance-covariance matrixes in unit value and quantity equations are defined as below:

(6) $$\Sigma = \begin{bmatrix} \sigma_u^2 + \sigma_e^2 & \sigma_u^2 & \cdots & \sigma_u^2 \\ \sigma_u^2 & \sigma_u^2 + \sigma_e^2 & \cdots & \sigma_u^2 \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_u^2 & \sigma_u^2 & \cdots & \sigma_u^2 + \sigma_e^2 \end{bmatrix}_{T_i x T_i} \text{ and } \Omega = \begin{bmatrix} \sigma_v^2 + \sigma_\varepsilon^2 & \sigma_v^2 & \cdots & \sigma_v^2 \\ \sigma_v^2 & \sigma_v^2 + \sigma_\varepsilon^2 & \cdots & \sigma_\varepsilon^2 \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_v^2 & \sigma_v^2 & \cdots & \sigma_v^2 + \sigma_\varepsilon^2 \end{bmatrix}_{T_i x T_i}.$$

The logarithm of (5) is:

(7) $$\begin{aligned} \ln L_i &= \ln f(\omega_i) + \ln f(D_i) + \ln f(\psi_i) \\ &= -T_i \ln(2\pi) - \frac{1}{2}\ln|\Sigma| - \frac{1}{2}\ln|\Omega| - \frac{1}{2}\omega_i'\Sigma^{-1}\omega_i - \frac{1}{2}\psi_i'\Omega^{-1}\psi_i + (\ln\lambda_i - \lambda_i D_i)J, \end{aligned}$$

where J is a T_i x 1 vector of ones. The log-likelihood for a total of N households is then,

(8) $$\ln L = \sum_{i=1}^{N} \ln L_i .$$

All parameter estimates can be obtained from maximizing (8). In estimation, we replace the actual values of unit value and inter-purchase time with their expected values, which are derived below, in the right hand side of the inter-purchase time equation and the quantity equation to correct for possible endogeniety bias. We also need to drop at least one variable in *X* from the inter-purchase time equation and the quantity equation for model parameter identification.

Given the model independency, the expectation of unit value, inter-purchase time, and quantity are derived as:

(9) $$E(V_{it}) = X_i\beta_1 + Z_t\beta_2$$

(10) $$E(D_{it}) = \frac{1}{\lambda_{it}} = \frac{1}{e^{X_i\gamma_1 + W_{it}\gamma_2 + E(V_{it})\gamma_3}}$$

(11) $$E(Q_{it}) = X_i\alpha_1 + Z_t\alpha_2 + W_{it}\alpha_3 + E(V_{it})\alpha_4 + E(D_{it})\alpha_5$$

The marginal effects of all the explanatory variables and their associated elasticities can be derived based on (9)-(11).

U.S. Household Vegetable Purchases

Data and Variables

This study is concerned with weekly purchases of vegetables for home consumption only. Weekly household purchase quantities and expenditures are defined as the sum of quantities and expenditures on all types of vegetables in all formats, such as fresh, dried, and canned, that are purchased within that week. As shown in the previous section, unit values capture both price and quality. They are derived by dividing reported expenditures by quantities for the purchase weeks. Table 1 gives a summary of U.S. households' vegetable purchases based on our sample of 2004 Nielsen Homescan data. We have a total of 52 weeks for 8,475 households in the final sample.

There are 185 households who did not buy any vegetables in 2004, and 485 households who bought only one or two times. We delete these households that made two or less purchases (7.9%) from our estimation. We need at least two inter-purchase time observations (three purchase observations) for each household to make the estimation stable (Boizot et al.).

U.S. households purchased vegetables in about 18 of the 52 weeks of 2004, on average, which implies that the mean inter-purchase time is 3.67 weeks. It indicates that, on average, Americans buy vegetables a little bit more often than once a month. During the weeks when a purchase is made, the average quantity bought was 2.9 lbs., and the unit value was $1.46/lb.

Table 2 lists all the explanatory variables used in the model and provides descriptive statistics on each. We use the inverse of household size to convert this number from a discrete variable into a continuous one and take the natural logarithm of household income. Mean income is $54,272, and the mean household size is 2.38.

Model Estimation Results

The three equations, unit value, inter-purchase time, and quantity, are jointly estimated using the maximum likelihood estimation (MLE) procedure described in the second section of this paper. However, since the three equations are independent, we could have also estimated these three equations one by one. We would not expect much difference from the two estimators.

Table 3 contains the results of model estimation. For model identification, we dropped the age and region variables from the inter-purchase time and quantity equations. Most of the variables are statistically significant at the 5% and 1% levels. The variances capturing the random effects in both the unit value and quantity equations are also highly significant.

Variable elasticities from these parameter estimates are derived based on equations (9)-(11). The results are provided in Table 4. The exogenous variables not only have a direct effect on the unit value, inter-purchase time, and quantity, but also an indirect effect on the inter-purchase time and quantity via the unit value, and an indirect effect on the quantity via both the unit value and inter-purchase time. For the unit value, since all the right-hand-side variables are exogenous, the direct and total effects are the same.

1. Unit value and quality

We find income, employment of the female head, and education of the female head to be positively related to vegetable quality choices. Specifically, households with a higher income, working female head, or a post-high school educated meal planner, tend to spend more money per unit on vegetables. In terms of ethnicity, Caucasian households would like to spend more per unit on vegetables than others. Larger-sized households are found to purchase cheaper vegetables, which may reflect a tighter per capita budget relative to smaller-sized households. Age of the female head of household has a large impact on vegetable quality choices. A 1% increase in the female head's age would decrease per unit vegetable spending by 0.25%. This may suggest older people are more frugal. We also find that people residing in the Central states (the base) spent more money per unit on vegetables than people in all other areas. Seasonality is assumed to capture changes in prices over time. We find in this study that people spent less per unit on vegetables in the winter (the base) than in other seasons. Given that fresh vegetables are often more expensive in winter, this seemingly unintuitive result may suggest that people turn to canned, dried, or other processed forms of vegetables in the winter in order to achieve their quantity goal without expanding their food budget.

2. Inter-purchase time or purchase frequency

Inter-purchase time captures purchase frequency. Among our results, we find the unit value is positively related to inter-purchase time. This indicates that paying more money for vegetables causes households to wait a longer period of time before making their next purchase. The elasticity with respect to the unit value is about 2.3, implying that a 1% increase in the predicted unit value would increase the inter-purchase time by 2.3%.

The direct and total effects of the exogenous variables on the inter-purchase time are provided in Table 4. The total effects are the sum of the direct and indirect effects. The indirect effects are derived from the change in the unit value. For example, the total effect of income, -0.0518, is the sum of the direct effect, -0.2028, and the indirect effect, 0.0658 x 2.2968 = 0.1510. Income directly reduced vegetable inter-purchase time, but it also increased the unit value, which in turn increased inter-purchase time. As a result, the total effect of income on inter-purchase time became smaller in magnitude.

Larger-sized households are found to buy vegetables more frequently than smaller-sized ones with or without considering the change through the unit value. The age of the female head does not directly enter the inter-purchase time equation, but has an effect on the inter-purchase time through the unit value with a large elasticity of -0.5709. Households with a working female head purchased vegetables less frequently, while households with post-high school educated female head purchased vegetables more frequently. For ethnicity, Caucasian households purchased vegetables more often than all other races if the change through unit value is not considered. However, if the change in the unit value is considered, Hispanic and Asian households would buy more often than Caucasian and African-American households. This could imply that, if the store provided only one choice of vegetable, Caucasians would buy more often, while if more vegetable varieties were provided, Hispanic and Asian households would buy more often. For regions, we find people living in the central area usually purchased vegetables less frequently than people living in other areas.

In this study, we also found that people made vegetable purchases more often in spring and summer, if the effect of the change in the unit value is not considered. However, people purchase more frequently in winter, if the effect of the change in the unit value is taken into account.

Promotions and coupons are found to shorten inter-purchase time, but the elasticities are very small. One reason may be the nature of our vegetable purchase data. Only a small proportion of all the foods were sold on a promotion or with a coupon.

3. Quantity

Both unit value and inter-purchase time are found to significantly affect purchase quantity. In this study (Table 4), we find that a 1% increase in the inter-purchase time would cause an increase of 0.42% in the quantity of vegetables purchased. This finding verifies our a priori expectation that the longer the inter-purchase time, the more the purchase quantity.

The elasticity of quantity with respect to the unit value is found to be -2.805, if we consider only the direct effect of the unit value, but the total elasticity is found to be -1.839. The total effect on quantity is smaller in magnitude because of the unit value's indirect effect through the inter-purchase time. Promotion and coupon are also found to be helpful for increasing vegetable purchase quantity.

Household income, household size, and the age of the female head of household are all found to have a positive effect on vegetable purchase quantity. As compared with the direct effects of these variables, the total effect of income was smaller while the total effect of household size was larger. Education did have a positive direct effect on quantity. However, since its negative indirect effect on quantity through both the unit value and inter-purchase time were larger, the total effect of education on quantity became negative. Regarding the total effects, Caucasian households and households residing in the central area are found to purchase a smaller quantity. Interestingly, we find that, in winter, people purchased more inexpensive vegetables, but less often and in smaller quantities.

Policy Implications and Conclusions

A household's demand for food can be described along three dimensions: how much food is bought, what types of food are bought, and how often food is bought. We have proposed a model in which these three facets of purchase behavior are simultaneously determined. Among other things, our model allows us to ask whether a household's frequency of purchase influences how much food is bought on any shopping occasion. This was not possible with past studies. We find that, in fact, the more time has elapsed between purchases, the greater the quantity of product a household will buy on its next shopping occasion.

Our model may be further developed and used to simulate the effects of government policies and marketing promotions. For example, the U.S. Department of Agriculture encourages Americans to incorporate a certain amount of fruits and vegetables into their daily diets. However, fruits and vegetables are vastly under-consumed by Americans. Policy options may include subsidies to lower vegetable prices, issuing coupons, or other types of promotions to raise fruit and vegetable consumption to the recommended levels. The effectiveness of such strategies depends on how households react.

Our model can be used to infer how several policy options may affect household behavior. We find that lower prices, coupons, and other promotions may all motivate households to buy vegetables more often. Thus, the inter-purchase time decreases. These policy tools may also encourage households to buy a greater quantity of vegetables. Paying less for food, using coupons, and taking advantage of promotions are all associated with buying more vegetables.

However, our approach allows for deeper insights than do models employed in past studies. Our model further accounts for the interplay between purchase quantity and inter-purchase time. For every 1% decrease in the inter-purchase time, we find that households will decrease the quantity of vegetables purchased on any shopping occasion by 0.42%. In other words, because they buy more often, households buy less each time they shop. And the total effect of each variable on purchase quantity is therefore smaller than is the direct effect.

Even stronger results are found with respect to household income. Our results suggest that higher income households buy higher quality vegetables and purchase vegetables more frequently. These habits tend to reduce the amounts they buy on any single occasion. In this study, the direct effect of income on purchase quantity was positive and large (0.2325). The total effect was comparatively small (0.0262), barely still positive.

Generally speaking, the model employed in this paper may be useful whenever a policy tool or marketing strategy can have two effects. First, households may be encouraged to purchase a greater (smaller) quantity each time they buy. Second, they may be encouraged to buy goods more (less) often.

The interplay between how often households buy and how much they buy at one point in time can be important. Retailers may have higher costs for handling inventory the more demand fluctuates. And, if we were to consider the demand for highly perishable foods, such as fresh vegetables or fresh fruits, purchases and consumption would be tightly correlated.

After further development, the model presented in this study may be used for a variety of marketing and policy simulation purposes. For example, we recognize that our choice of exogenous variables for the unit value equation could be improved so that it is not necessary to use ad hoc instruments for the sake of identification. The quantity of vegetables might also be defined on a per serving basis instead of on a per pound basis. Furthermore, the model could be adjusted to account for the sampling properties of our Nielsen Homescan data. The goal of this paper has been to present the model in the simplest possible form, and to illustrate its potential with an application to the quality, quantity, and frequency of a household's vegetable purchases.

Table 1. U.S. Households' Vegetable Purchases in 2004

Purchase Variable	mean	standard error
Number of households	8,475	0
Number of households made zero purchases	185	0
Number of households made only one or two purchases	485	0
Number of total weeks	52	0
Number of purchase weeks	17.9	11.7
Inter-purchase time (week)	3.67	2.86
Quantity purchased over purchase weeks (pounds)	2.90	1.76
Unit value paid ($/pounds)	1.46	0.86

Table 2. Variable Descriptive Statistics

variable name	description	Used in equation	mean	standard error
		Household variables		
interc	intercept	V, D, Q*	1	0
lnincome	natural logarithm of household income (ln $)	V, D, Q	10.7	0.69
invhhsize	inverse of household size (1/number)	V, D, Q	0.55	0.29
fage	age of female head (number)	V	52.1	11.7
femp	=1 if female head is employed	V, D, Q	0.44	0.50
fedu	=1 if education of female head is above high school	V, D, Q	0.40	0.49
black	=1 if household is Black	V, D, Q	0.14	0.34
hisp	=1 if household is Hispanic	V, D, Q	0.08	0.28
asian	=1 if household is Asian	V, D, Q	0.03	0.18
east	=1 if household resides in the East	V	0.22	0.41
south	=1 if household resides in the South	V	0.39	0.49
west	=1 if household resides in the West	V	0.22	0.42
		Seasonality variables		
spring	=1 if purchases made in spring	V, D, Q	0.27	0.13
summer	=1 if purchases made in summer	V, D, Q	0.28	0.13
fall	=1 if purchases made in fall	V, D, Q	0.25	0.13
		Marketing variables		
promotion	=1 if purchases made on promotion	D, Q	0.23	0.25
Coupon	redeemed coupon values ($)	D, Q	0.03	0.13

* V, D, and Q represent unit value, inter-purchase time, and quantity equations, respectively.

Table 3. Parameter Estimates

	Unit Value		Inter-purchase Time		Quantity	
variable	coefficient	std. error	coefficient	std. error	coefficient	std. error
			household variables			
interc	-0.3248*	0.0632	-2.6266*	0.1671	-2.7612	1.5500
lnincome	0.0653*	0.0056	0.2021*	0.0163	0.5718*	0.1243
invhhsize	0.0427*	0.0139	-0.0546	0.0308	-0.8058*	0.1457
fage	-0.0048*	0.0003	--	--	--	--
femp	0.0080	0.0081	-0.0903*	0.0193	-0.1356	0.0939
fedu	0.0340*	0.0078	0.1045*	0.0195	0.3247*	0.0995
black	-0.0998*	0.0107	-0.3936*	0.0298	-0.4529	0.2369
hisp	-0.0350*	0.0122	-0.0560	0.0288	0.1113	0.1284
asian	-0.0960*	0.0197	-0.1283*	0.0479	0.5918*	0.2071
east	-0.0194*	0.0022	--	--	--	--
south	-0.0271*	0.0025	--	--	--	--
west	-0.0442*	0.0036	--	--	--	--
			Seasonality variables			
spring	0.0291*	0.0041	0.0511*	0.0137	0.1330*	0.0542
summer	0.0565*	0.0038	0.0111	0.0148	0.0357	0.0578
fall	0.0099*	0.0041	-0.1835*	0.0120	-0.2052*	0.0957
			marketing variable			
promotion	--	--	0.0370*	0.0043	0.0961*	0.0263
Coupon	--	--	0.0134*	0.0056	0.6449*	0.0182
E(V)	--	--	-2.3041*	0.1662	-6.9632*	1.3596
E(D)	--	--	--	--	0.3966*	0.1972
			variance			
σ_u^2	0.0738*	0.0006	--	--	--	--
σ_e^2	0.2545*	0.0004	--	--	--	--
σ_v^2	--	--	--	--	2.4364*	0.0702
σ_ε^2	--	--	--	--	8.5966*	0.0309

* indicates significant at 5% level.

Table 4. Elasticity Estimates

	Unit Value	Inter-purchase Time		Quantity	
variable	direct/total	direct	total	direct	total
		Household variables			
income	0.0658	-0.2028	-0.0518	0.2325	0.0262
hhsize	-0.0909	-0.1389	-0.3476	0.6587	0.7674
fage	-0.2485	--	-0.5709	--	0.4571
femp	0.0028	0.0412	0.0476	-0.0239	-0.0117
fedu	0.0131	-0.0406	-0.0105	0.0402	-0.0010
black	-0.0135	0.0532	0.0222	-0.0145	0.0327
hisp	-0.0029	0.0044	-0.0022	0.0036	0.0107
asian	-0.0032	0.0042	-0.0031	0.0054	0.0130
east	-0.0039	--	-0.0089	--	0.0071
south	-0.0104	--	-0.0238	--	0.0191
west	-0.0096	--	-0.0220	--	0.0176
		Seasonality variables			
spring	0.0079	-0.0137	0.0045	0.0156	-0.0047
summer	0.0155	-0.0034	0.0321	0.0068	-0.0230
fall	0.0026	0.0458	0.0517	-0.0215	-0.0069
		Marketing variables			
promotion	--	-0.0090	-0.0090	0.0076	0.0038
Coupon	--	-0.0004	-0.0004	0.0056	0.0054
E(V)	--	2.2968	2.2968	-2.8050	-1.8390
E(D)	--	--	--	0.4206	0.4206

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