The Demand for Fruit Juices: Market Participation and Quantity Demanded

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The quantity demanded in a market can be decomposed into two components: the number of purchasers and the quantity per purchaser. Focusing on these two components, the demands for different types of single-flavor fruit juice commodities are analyzed. The approach allows the market demand elasticities to be estimated as the sum of the elasticity estimates for the numbers of purchasers and the elasticity estimates for the quantities per purchaser. The method of seemingly unrelated regressions is employed to estimate the equations for the two demand components for the different types of juice.

Key words: demand, elasticity, fruit juice, market participation.

In recent years, increasing attention has been given to the discrete and continuous consumer choices regarding whether or not to purchase a commodity and the quantity purchased (Tobin; Amemiya; Lee and Trost; Thraen, Hammond, and Buxton; McDonald and Moffitt; Myers and Liverpool; Tilley; Maddala; Hanemann 1982, 1984; Wales and Woodland; Jackson; among others). Both choices are important in understanding and describing consumer behavior and have been applied widely in empirical analysis. As in the case of Tobin's model, much of the analysis has been based on microdata involving zero and positive quantities purchased; however, more aggregate data on percentages of consumers purchasing and average quantities purchased have also been employed (e.g., Myers and Liverpool; and Tilley). In this paper, the latter type of data is employed to analyze consumer behavior. Specifically, with information on the number of purchasers (n) and the average quantity per purchaser ($\bar{q}$), total demand (q) can be specified as $q = n\bar{q}$. The analysis can then focus on the separate components n and $\bar{q}$. For example, letting n and $\bar{q}$ be functions of say price p, the effect of price on total demand can be decomposed into two parts: (a) a market participation effect and (b) a quantity effect. In terms of elasticities, this decomposition is $\epsilon_{q,p} = \epsilon_{n,p} + \epsilon_{\bar{q},p}$, where in general $\epsilon_{y,x}$ is the elasticity of y with respect to x. Thraen, Hammond, and Buxton provide a similiar decomposition.

In this paper, the single-flavor fruit juice market is analyzed with respect to the number of purchasers and the average quantity per purchaser for specific types of fruit juices. Four single-flavor fruit juices—orange juice (*OJ*), grapefruit juice (*GFJ*), apple juice (*AJ*), and grape juice (*GRPJ*)—are examined. Based on data from NPD Research, these four juices comprise the majority of the single-flavor fruit juice market sales, representing 87% and 89% of the U.S. market in terms of dollar and single-strength-equivalent gallon sales, respectively, in April 1985. Market summary data for the period 1978–85 provided by NPD Research indicate that *OJ* has been the dominant type of juice followed by *AJ* with *GFJ* and *GRPJ* having had relatively smaller market shares. The data show that dollar sales have tended to increase steadily for each juice with the exception of *GFJ*, which experienced some ups and downs and *OJ*, which experienced a decrease in sales in 1983. *AJ* experienced the most dramatic increase in dollar sales, more than doubling over the period. Sales in terms of single-strength-equivalent gallons also roughly doubled for *AJ* over these years but were more variable than dollar sales for the other juices. The data also reveal that the num-

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ber of households purchasing *AJ* and *GRPJ* have been steadily increasing, while the number purchasing *OJ* and *GFJ* have tended to be somewhat variable. In addition, the single-strength-equivalent ounces purchased per household have tended to increase for *AJ* with slight to moderate fluctuations for the other juices.

Model

The demand analysis for the four juices—OJ, GFJ, AJ, and *GRPJ*—is based on eight equations. For each juice there are two equations: one for the number of households purchasing and the other for the average quantity purchased per household. The equations are specified in double logarithmic form as

$$(1)\quad \log n_{it} = \alpha_{i1} + \sum_{j=2}^{12} \alpha_{ij}M_{jt} + \alpha_{i13}\log I_t + \sum_{j=1}^{4} \alpha_{i,j+13}\log P_{jt} + \alpha_{i18}\log POP_t + \alpha_{i19}\log n_{it-1}$$

$$(2)\quad \log \bar{q}_{it} = \beta_{i1} + \sum_{j=2}^{12} \beta_{ij}M_{jt} + \beta_{i13}\log I_t + \sum_{j=1}^{4} \beta_{i,j+13}\log P_{jt} + \beta_{i18}\log \bar{q}_{it-1},$$

where subscripts i and t indicate the type of juice ($i = 1$ for *OJ*, $i = 2$ for *GFJ*, $i = 3$ for *AJ*, and $i = 4$ for *GRPJ*) and time (monthly), respectively; n and $\bar{q}$ are the number of households purchasing and the average quantity in single-strength-equivalent gallons per purchasing household, respectively; $M_j = 1$ if in the jth month of the year ($j = 1$ for January, $\ldots, j = 12$ for December), 0 otherwise; I is per capita real income (nominal U.S. personal income divided by the U.S. population divided by the consumer price index [CPI]); P_j is the real CPI deflated price of the jth juice (j identifies the juice price according to the definition of i above); *POP* is the U.S. population in thousands; and the αs and βs are parameters to be estimated. Both equations are specified with a lag [n_{it-1} in equation (1) and $\bar{q}_{it-1}$ in equation (2)], allowing for inventory and habit effects. With these lagged variables, the equations follow the dynamic flow adjustment proposed by Houthakker and Taylor and discussed by Tilley with regard to orange juice consumption.

The equations characterize the discrete and continuous choices discussed by Hanemann (1982, 1984) and Jackson (the discrete choice concerns whether or not the commodity is purchased, while the continuous choice concerns the quantity purchased), with the double logarithmic specifications regarded as behavioral approximations. Similar double logarithmic specifications are employed by Tilley in studying frozen concentrated orange juice and chilled orange juice. Based on corner solution results (Hanemann 1984 and Jackson, among others), the decision to purchase a commodity and the quantity demanded both depend on prices, income, preferences, and perhaps other exogenous factors (Hanemann 1982, 1984). Specification (2), the demand for the average household, follows directly, interpreting the monthly dummy variables and the lagged quantity variable as preference shifters and including per capita income as a measure to account for the impact of household income. Similarly equation (1) follows, with the population variable included as an approximation for the potential number of purchasing households.

Data

Monthly time-series data for the total U.S. from NPD Research and the Survey of Current Business were used in the analysis of this study. The period analyzed was from December 1977 through April 1985, providing 89 observations. The NPD Research data were generated for the Florida Department of Citrus from a diary-based survey of about 6,500 households nationwide. For each type of juice, NPD Research provided data on the number of households purchasing, the quantity per purchasing household, and the total dollar and quantity sales for which implicit prices were derived. The *Survey of Current Business* provided data on total U.S. personal income, the consumer price index, and the U.S. population.

Estimation and Results

The equations defined by specifications (1) and (2) are estimated by Zellner's method of seem-

Table 1. Seemingly Unrelated Regression Results for the Number of Purchasing Households (n) and the Quantity per Purchasing Household ($\bar{q}$), Based on 1977-85 Monthly Data

Independent[a] Variables	Dependent Variable[a,b]							
	OJ		*GFJ*		*AJ*		*GRPJ*	
	n_{1t}	$\bar{q}_{1t}$	n_{2t}	$\bar{q}_{2t}$	n_{3t}	$\bar{q}_{3t}$	n_{4t}	$\bar{q}_{4t}$
I	1.359[c]	.762	−.281	−.029	−.454	−.123	−.141	−1.221
	(.234)[d]	(.321)	(.684)	(.475)	(.381)	(.292)	(.649)	(.437)
P_1	−.663	−.728	.302	.086	.005	−.103	.303	.364
	(.082)	(.112)	(.214)	(.149)	(.110)	(.095)	(.208)	(.137)
P_2	.298	.290	−.319	−.304	.144	.070	.168	.025
	(.048)	(.066)	(.144)	(.097)	(.070)	(.059)	(.130)	(.086)
P_3	.292	.616	−.122	.309	.001	−.151	−.739	.699
	(.127)	(.092)	(.394)	(.138)	(.207)	(.078)	(.404)	(.130)
P_4	−.078	−.115	.041	−.140	.115	−.103	−.196	−.957
	(.055)	(.082)	(.176)	(.124)	(.089)	(.076)	(.164)	(.122)
POP	.630		−2.537		4.496		2.534	
	(.635)		(2.031)		(1.434)		(2.010)	
$n_{1,t-1}$ or $\bar{q}_{1,t-1}$[e]	.059	−.079						
	(.079)	(.089)						
$n_{2,t-1}$ or $\bar{q}_{2,t-1}$[e]			.403	.130				
			(.101)	(.109)				
$n_{3,t-1}$ or $\bar{q}_{3,t-1}$[e]					.582	.249		
					(.094)	(.106)		
$n_{4,t-1}$ or $\bar{q}_{4,t-1}$[e]							.089	.155
							(.103)	(.079)

[a] The dependent variables are the logarithms of n_i and $\bar{q}_i$ while the independent variables are the logarithms of I, the P_i's, *POP*, and the lagged dependent variables. See equations (1) and (2) for more exact definitions.
[b] The weighted R^2 for the system was .90. For the initial OLS regressions, the R^2's were .87, .69, .79, .45, .98, .74, .85, and .76 for the equations defined for n_1, $\bar{q}_1$, n_2, $\bar{q}_2$, n_3, $\bar{q}_3$, n_4, and $\bar{q}_4$, respectively.
[c] Coefficient estimate.
[d] Asymptotic standard errors in parentheses.
[e] The estimates are for n_{it-1} when the dependent variable is n_{it} and for $\bar{q}_{it-1}$ when the dependent variable is $\bar{q}_{it}$, i = 1, 2, 3, and 4.

ingly unrelated regressions to take advantage of the contemporaneous disturbance correlations across equations. Autocorrelation is rejected based on tests suggested by Durbin. The estimates are reported in table 1. For economy of space, the intercept and monthly dummy variable coefficient estimates are not reported. Employment of the monthly dummy variables appears to have adequately taken into account seasonality based on each equation's correllogram for the residuals. The coefficient estimates for the dummy variables, in general, indicate that all eight equations were influenced to various extents by season of the year.

The weighted R-squared for the system of equations in table 1 is .90. Given the double logarithmic specifications, the coefficient estimates in the table are interpreted as elasticities. The estimates for the equations indicating the number of households purchasing are given in columns 1, 3, 5, and 7. The income elasticity estimates for all equations except for *OJ* are insignificant, based on the associated asymptotic t-values. For the *OJ* equation, a one percent increase in real per capita income increases the number of households purchasing by about 1.4%. The own-price elasticity estimates are negative, except for *AJ* which, along with estimate for *GRPJ*, is not significantly different than zero. The own-price elasticity estimates for purchasing *OJ* and *GFJ* are −.66 and −.32, respectively, both estimates being significant. A number of the cross-price elasticity estimates are insignificant. However, in the *OJ* equation, the *GFJ* and *AJ* cross-price estimates indicate substitute relationships. The same is true for the *AJ* equation with respect to the *GFJ* price, while in the *GRPJ* equation the *AJ* price estimate indicates a complementary relationship. As expected, the population elasticity estimates are positive, except for *GFJ*. However, except for *AJ*, they are insignificant. The elasticity estimates for the lagged dependent variables are all positive and, except for *OJ* and *GRPJ*, significant, indicating persistence in purchasing.

Turning to the estimates for the single-strength-equivalent gallons per household, the

Table 2. Total Elasticities

Item	Juice			
Income (I)	2.121[a] (.450)[b]	−.310 (.771)	−.577 (.462)	−1.362 (.768)
Prices OJ (P_1)	−1.391 (.155)	.388 (.242)	−.098 (.140)	.667 (.244)
GFJ (P_2)	.588 (.092)	−.623 (.163)	.214 (.088)	.193 (.153)
AJ (P_3)	.908 (.170)	.187 (.406)	−.150 (.218)	−.040 (.422)
$GRPJ$ (P_4)	−.193 (.112)	−.099 (.199)	.012 (.112)	−1.153 (.201)

Note: Calculated from table 1 as the sum of elasticities for the number of purchasers and quantities per purchaser: $\epsilon_{q,x} = \epsilon_{n,x} + \epsilon_{\bar{q},x}$ where q is the total quantity purchased, n is the number of purchasers, $\bar{q}$ is the quantity per purchaser and x stands for a price or income.
[a] The elasticity estimate $\epsilon_{q,x}$.
[b] Asymptotic standard error for the elasticity.

income elasticity estimates for *OJ* and *GRPJ* are .76 and −1.22, respectively, both being significant. The income elasticity estimates for the other types of juice are insignificant. Consistent with theory, all own-price elasticity estimates are negative and significant, ranging from −.96 for *GRPJ* to −.15 for *AJ*. Five out of the twelve cross-price effects are significant and positive, indicating a predominance of substitute and neutral relationships. The cross-price elasticities range from .29 for the *GFJ* price in the *OJ* equation to .70 for the *AJ* price in the *GRPJ* equation. The elasticity estimates for the lagged dependent variables are positive and significant for *AJ* and *GRPJ* but insignificant for the *OJ* and *GFJ* equations. This may indicate that the habit effect dominates the inventory effect for the former two types of juice, while the two effects cancel each other out for the latter two types of juice (Sexauer). Given the types of juice are defined to include both frozen concentrate and ready-to-serve products, this result is not unexpected (Tilley).

The separate equation estimates in table 1 can be combined in various ways to further examine the market for single-flavor fruit juices. For example, since the total market quantity (q) is defined as the product of the number of purchasers (n) and the quantity per purchaser ($\bar{q}$), the elasticity for the total market quantity with respect to one of the predetermined variables x equals the sum of the elasticities with respect to x for the number of purchasers and the quantity per purchaser, i.e., $\epsilon_{q,x} = \epsilon_{n,x} + \epsilon_{\bar{q},x}$. Applying this result, the own-price elasticities for the total market are −.728 + −.663 = −1.39 for *OJ*, −.304 + −.319 = −.62 for *GFJ*, −.151 + .001 = −.15 for *AJ*, and −.957 + −.196 = −1.15 for *GRPJ*. The full set of such total elasticities with standard errors with respect to income and prices is given in table 2. The estimates are not directly comparable to other published results, but with regard to *OJ*, Ward and Tilley, and Tilley found similar results for frozen concentrated orange juice (*FCOJ*) and chilled orange juice (*COJ*). The own-price elasticities for *FCOJ* and *COJ* were found to be about −1.4 and −.43, respectively, by Tilley; and about −1.35 and −.93, respectively, by Ward and Tilley. The Tilley elasticities and those in the present paper can be interpreted as short-run elasticities. Corresponding long-run elasticities can be derived as discussed by Tilley.

Another potentially useful combination of the equation estimates focuses on relative juice market shares. For example, the *AJ* quantity share relative to the *OJ* share is $w_{31} = q_3/q_1 = (n_3\bar{q}_3)/(n_1\bar{q}_1)$. Taking logarithms, $\log q_3 - \log q_1 = \log n_3 - \log n_1 + \log \bar{q}_3 - \log \bar{q}_1$, and the elasticity of the *AJ–OJ* relative share with respect to x is $\epsilon_{w31,x} = \epsilon_{n3,x} - \epsilon_{n1,x} + \epsilon_{\bar{q}3,x} - \epsilon_{\bar{q}1,x}$. Applying this result to the estimates in table 1, the *AJ–OJ* relative quantity share elasticities with respect to income, the price of *OJ* and the price of *AJ* are −2.70, 1.29, and −1.06, respectively. (A 1.0% increase in income decreases the share q_3/q_1 by 2.70%; a 1.0% increase in the price of *OJ* increases the share by 1.29%; and a 1.0% increase in the price of *AJ* decreases the share by 1.06%.) Other relative shares can be similarly examined.

These applications and others allow an understanding of market behavior and as such are potentially useful in marketing. Knowledge of the relationships between different commodity demands focusing on the numbers of purchasers and the quantities per purchaser can be important information.

Summary

The quantity demanded in a market can be broken down into two components: the number of purchasers and the quantity per purchaser. Changes in market demand can be analyzed by examining these two components separately. Such an examination is made for the single-flavor fruit juice market in this paper. The approach allows the market demand elasticities to be estimated as the sum of elasticity estimates for the number of purchasers and the quantities per purchaser. The method of seemingly unrelated regressions is employed to estimate the equations for the number of purchasers and the quantities per purchaser.

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References

Amemiya, T. "Tobit Models: A Survey." *J. Econometrics* 24(1984):3–61.

Durbin, J. "Testing for Serial Correlation in Least-Squares Regression When Some of the Regressors Are Lagged Dependent Variables." *Econometrica* 38(1970):410–21.

Hanemann, W. M. "Discrete/Continuous Models of Consumer Demand." *Econometrica* 52(1984):541–61.

———. "Quality and Demand Analysis." *New Directions in Econometric Modeling and Forecasting in U.S. Agriculture,* ed., G. C. Rausser. New York: North-Holland Publishing Co., 1982.

Houthakker, H. S. and L. D. Taylor. *Consumer Demand in the United States,* 2nd ed. Cambridge MA: Harvard University Press, 1970.

Jackson, L. F. "Hierarchic Demand and the Engle Curve for Variety." *Rev. Econ. and Statist.* 62(1984):318–21.

Lee, L. F., and R. P. Trost. "Estimation of Some Limited Dependent Variable Models with Applications to Housing Demand." *J. Econometrics* 8(1978):357–82.

McDonald, J. F., and R. A. Moffitt. "The Uses of Tobit Analysis." *Rev. Econ. and Statist.* 62(1980):318–21.

Maddala, G. S. *Limited-Dependent and Qualitative Variables in Econometrics.* New York: Cambridge University Press, 1983.

Myers, L. H., and L. Liverpool. "Demand Interrelationships among Orange Beverages." Econ. Res. Dep. Rep. FCC-ERD 72-1, Florida Department of Citrus and University of Florida, Feb. 1972.

NPD Research, Inc. "Market Summary of the Beverage Category." Prepared for the Florida Department of Citrus, Dec. 1977 through Apr. 1985, Flora Park, New York.

Sexauer, B. "The Role of Habits and Stocks in Consumer Expenditures." *Quart. J. Econ.* 91(1977):127–42.

Thraen, C. S., J. W. Hammond, and B. M. Buxton. "Estimating Components of Demand Elasticities from Cross-Sectional Data." *Amer. J. Agr. Econ.* 60(1978):674–77.

Tilley, D. S. "Importance of Understanding Consumption Dynamics in Market Recovery Periods." *S. J. Agr. Econ., no. 2* (Dec. 1979), pp. 41–46.

Tobin, J. "Estimation of Relationships for Limited Dependent Variables." *Econometrica* 26(1958):24–36.

U.S. Department of Commerce, Bureau of Economic Analysis. *Survey of Current Business.* May 1972 through July 1983.

Wales, T. J., and A. D. Woodland. "Estimation of Consumer Demand Systems with Binding Non-Negativity Constraints." *J. Econometrics* 21(1983):263–85.

Ward, R. W., and D. S. Tilley. "Time-Varying Parameters with Random Components: The Orange Juice Industry." *S. J. Agr. Econ., no. 2* (Dec. 1980), pp. 5–13.

Zellner, A. "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias." *J. Amer. Statist. Assoc.* 57(1962):348–68.