Orange Juice Market Participation: A Multinomial Logit Analysis of Frequency Data on Purchases of Alternative Product Forms

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Abstract

The multinomial logit model allowing for specification error was used to analyze frequency data on the number of households purchasing alternative forms of orange juice. The results indicate that the odds of choosing frozen concentrated orange juice, ready-to-serve orange juice or both product forms relative to the choice of not consuming orange juice increase or remain unchanged with income, have negative own-price and positive or neutral cross-price relationships, decrease in the summer, and are positively related to the previous period's odds, suggesting the influence of habits in market participation.

Key words: orange juice, frozen, ready-to-serve, market participation, multinomial logit.

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Market participation is an important aspect of orange juice demand. The demand for orange juice, or any product in general, can be decomposed into two parts: a market-participation component involving number of buyers and a quantity-per-buyer component. The decomposition can be useful for understanding and describing consumer behavior and has received increasing attention in the literature (e.g., Tobin; Amemiya, 1984; Lee and Trost; Thraen, Hammond, and Buxton; McDonald and Moffitt; Myers and Liverpool; Tilley; Hanemann; Wales and Woodland; Brown). In particular, Brown's study indicates the importance of market participation for orange juice. In that study the own-price elasticity for orange juice was found to be -1.4 with about half the effect due to consumers entering or exiting the market and the other half related to changes in quantities purchased per buyer. Although sellers are ultimately interested in total demand, information on the decomposition of demand can be useful. For example, in developing advertising and promotional programs, information on market participation, as well as information on quantity demanded, can be useful in determining the different weights given to attracting new buyers and increasing the demands of repeat buyers.

In the present study, market participation for orange juice is further examined with attention focused on frozen concentrated orange juice (FCOJ) and ready-to-serve orange juice (RTSOJ). Frequency data related to number of purchasing households for four categories -- only

FCOJ consumers, only RTSOJ consumers, consumers of both FCOJ and RTSOJ, and nonconsumers of orange juice -- are analyzed using a multinomial logit model. Market participation in these categories has changed substantially in recent years, underlying the expansion in RTSOJ sales, and leveling off and decline in FCOJ sales. Retail grocery store sales data provided by A. C. Nielsen Co., show that from 1970-71 (December 1970 through November 1971) to 1985-86, sales of orange juice more than doubled, growing from 404.6 million single strength equivalent (SSE) gallons to 884.1 million SSE gallons. Over this period, RTSOJ gallon sales grew from 22.6% to 51.4% of the total gallon sales while FCOJ gallon sales fell from 77.4% to 48.6% of the total. Data on other fruit juices also indicate orange juice has been and continues to be the most popular fruit juice. In 1986 orange juice comprised 63.5% of total fruit juice gallon sales, and fruit juice gallons sales, overall, grew 38.8% from 1978 to 1986 (Stacy). Market participation data provided by NPD Research, Inc., provide insight into the changes in the orange juice market. The NPD data indicate that from 1977 to 1986 the annual average percentage of orange juice consumers who purchased only FCOJ fell from 72% to 50% while the percentage who purchased only RTSOJ rose from 21% to 39%, and the percentage who purchased both RTSOJ and FCOJ rose from 7% to 11%. Monthly NPD data indicate additional variation in the percentages associated with changes in prices, income, and other demand factors suggesting underlying causal relationships. These implied demand relationships are the focus of attention of the remainder of this paper.

Model

The multinomial logit (MNL) specification suggested by Parks was used to analyze the frequency data on purchasing different FCOJ-RTSOJ mixes. The MNL probability that a consumer chooses product mix i (i=0 for nonconsumers of orange juice, i=1 for only FCOJ consumers, i=2 for only RTSOJ consumers, and i=3 for consumers of both FCOJ and RTSOJ) in month t can be written as

$$(1)\quad P_{it} = \frac{e^{B_j' X_{it} + V_{it}}}{1 + \sum_{j=1}^{3} e^{B_j' X_{jt} + V_{jt}}}, \quad i = 1, 2, 3$$

$$P_{ot} = \frac{1}{1 + \sum_{j=1}^{3} e^{B_j' X_{jt} + V_{jt}}},$$

where the X's are vectors of explanatory variables, the B's are parameter vectors, and the V's are error terms associated with the specification. The probabilities are normalized with respect to the zero purchase category for convenience.

Replacing probability P_{it} in specification (1) with observed frequency f_{it}, defined as $f_{it}=n_{it}/n_t$ where n_{it} is the number of households in purchase category i and $n_t = \sum_{i=0}^{3} n_{it}$, and taking the logarithm of the odds of making choice i relative to the zero purchase category, the MNL model can be expressed as suggested by Parks as

$$(2)\quad \ln(f_{it}/f_{ot}) = B_i' X_{it} + V_{it} + U_{it} \qquad i = 1, 2, 3,$$

where an additional error term U_{it} associated with the observed frequencies has been introduced ($U_{it} = \ln(f_{it}/f_{ot}) - \ln(P_{it}/P_{ot})$). The error term U_{it} has traditionally been recognized (Theil, 1970) while the error term V_{it} has more recently been proposed by Amemiya and Nold in the binomial logit model and by Parks in the MNL model.

The error distribution assumptions for the model, following Parks, are

(3) $E(V_{it}) = E(U_{it}) = 0,$

(4) $E(V_{it} \cdot V_{jt'}) = \sigma_{ij}$ for $t=t'$ for all i and j,

$= 0$ for $t \neq t'$ for all i and j,

(5) $$E\begin{bmatrix} U_{1t} \\ U_{2t} \\ U_{3t} \end{bmatrix} [U_{1t}\ U_{2t}\ U_{3t}] = \frac{1}{n_t} \begin{bmatrix} \frac{1}{P_{ot}} + \frac{1}{P_{1t}} & \frac{1}{P_{ot}} & \frac{1}{P_{ot}} \\ \frac{1}{P_{ot}} & \frac{1}{P_{ot}} + \frac{1}{P_{2t}} & \frac{1}{P_{ot}} \\ \frac{1}{P_{ot}} & \frac{1}{P_{ot}} & \frac{1}{P_{ot}} + \frac{1}{P_{3t}} \end{bmatrix}, \text{ and}$$

(6) $E\,(V_{it}\ U_{jt'}) = 0$ for all i, j, t and t'.

Expressions (3) and (4) are the usual contemporaneous correlation assumptions for systems of simultaneous equations or seemingly unrelated equations while equation (5) indicates the traditional error structure used to estimate the MNL model.

The explanatory variables used in the analysis included the logarithms of the deflated prices of FCOJ and RTSOJ; the logarithm of deflated per capita income; a summer-winter dummy variable taking a value of one from May through August; and the lagged value of the dependent variable, the logarithm of the odds ratio. The latter variable was included to capture persistence in buying or inventory/habit effects (Tilley). Prices and income were also specified linearly but did not fit as well as the logarithmic specification. Selection of variables as well as the MNL model is based on previous theoretical and applied work (see Amemiya, 1981, and Maddala for discussion of the MNL model and examples of applied work). The MNL specification has also received considerable attention in demand analysis in recent years (e.g., Bewely, Bewely and Young, Tyrrell and Mount, Considine and Mount). A discussion of the discrete nature of the consumer choice is provided by Hanemann and Jackson.

Consistent and asymptotically efficient estimates of the MNL model described above can be obtained as discussed by Parks. Briefly, the Parks procedure obtains consistent estimates of equation (2) by using the ordinary least squares (OLS) method, estimating the MNL model covariance matrix using the OLS residuals and the observed frequencies, and applying the generalized least squares method. (Details of the estimature procedure are given by Parks, pp. 298-299.)

Data and Variables

Monthly time-series data on frequency of household purchases of the different orange juice mixes (f_{it}) were provided by NPD Research, Inc. The period analyzed was from December 1977 through August 1986, providing 105 observations. The NPD data were generated for the Florida Department of Citrus from a diary-based survey of about 6,500 households representative of the U.S. population. NPD also provided data on prices of FCOJ and RTSOJ which were used as explanatory variables. The prices are average retail prices actually paid by the households in the sample. The Survey of Current Business (U.S. Department of Commerce) provided data on total U.S. personal income, the consumer price index (CPI), and the U.S. population. The CPI was used to deflate the price and income data and the U.S. population was used to construct the per capita income data.

Results

Initially, consistent estimates of equation (2) were obtained using the OLS procedure. The coefficients of determination for the choice equations for FCOJ only, RTSOJ only, and both FCOJ and RTSOJ were .92, .73 and .61, respectively. The Durbin h-statistics indicate autocorrelation is not a problem (Appendix A). The OLS residuals for the choice equations were used in estimating the covariance matrix for the MNL model.

The MNL estimates based on the Parks procedure are provided in Table 1. For comparison, the MNL estimates based on the traditional procedure which ignores the contemporaneous correlation indicated by equations (3) and (4) are provided in Appendix B. The Parks and traditional coefficient estimates are roughly comparable, but the consistent coefficient standard error estimates for the traditional approach exceed those for the Parks model, although only slightly in this particular case. The coefficient standard error results are well known (Theil, 1971, p. 238); the latter, however, is not necessarily true when the contemporaneous correlations are ignored in estimating the coefficient covariance matrix for the traditional model. In this case, as shown in Appendix B, the coefficient standard errors are biased downward indicating the traditional model fits better than it actually does (a discussion of the bias is provided by Parks, pp. 300-302).

The results in Table 1 indicate how the different explanatory variables affect the logarithm of the odds of making a particular choice relative to the choice of not consuming orange juice. As a basis for interpretation, Table 2 shows trends in the frequencies and odds ratios underlying the model. The odds of choosing RTSOJ only and both FCOJ and RTSOJ have been increasing over time while the odds of choosing FCOJ only have been decreasing. The mean odds ratios for

FCOJ only, RTSOJ only, and both FCOJ and RTSOJ are .480, .219, and .071, respectively.

In Table 1, the coefficient estimates for the seasonal dummy variable which are statistically significant (a 5% level of significance is used throughout the analysis), indicate all three odds ratios tend to decrease in the summer. The results indicate the FCOJ-RTSOJ and FCOJ odds ratios decrease in the summer by about 8% and 7%, respectively, while the RTSOJ odds ratio decreases more moderately by about 3%. (Hereafter, FCOJ by itself refers to the FCOJ-only choice, RTSOJ by itself refers to the RTSOJ-only choice, and FCOJ-RTSOJ refers to the choice of FCOJ and RTSOJ.) Perhaps this result is related to changes in household eating behavior during the summer as children are let out of schools, recreational activities increase, and vacations are taken. Myers and Liverpool found season of the year to affect orange juice demand and suggested that during the summer there is probably more substitution of lemonade and Kool-Ade type drinks for frozen concentrates. The greater number of other substitutes during the summer, including the presence of Valencia and other juice oranges in the fresh market as well as the general abundance of fresh fruits and vegetables, may also be a possible explanation.

Given the logarithmic specification of equation (2), coefficients for the other variables can be interpreted as elasticities indicating percentage changes in the odds ratio for one-percent changes in the basis variable values. With the lagged dependent variable treated as a predetermined variable, these elasticities are actually short-run elasticities; for prices and income, long-run elasticity estimates can be found by dividing the short-run elasticity estimates by one minus the coefficient for the lagged variable (Tilley).

As reported in Table 1, income has a positive, significant effect on the odds for RTSOJ and FCOJ-RTSOJ with the elasticity estimates being 1.225 and 1.051, respectively. The income elasticity for the odds for FCOJ is not significantly different from zero. These results, along with the expectation that income will tend to increase in the future as in the past, indicate that the trends towards choosing RTSOJ and FCOJ-RTSOJ shown in Table 2 may continue. However, interpreting income as the causal factor should be treated cautiously. Other demand factors not analyzed due to data limitations may be correlated with income with the result that the income variable may be picking up the joint impact of such omitted demand factors. During the period studied, the orange juice market experienced increased marketing activity by new entrants and established firms. This activity may be related to the growth in RTSOJ market participation. Again, due to data limitations the impact of increased marketing activity could not be measured.

Consistent with theory, the own-price elasticities for the FCOJ and RTSOJ odds are -1.039 and -.730, respectively, both significant. The FCOJ and RTSOJ price elasticities for the FCOJ-RTSOJ odds are both negative but insignificant. The RTSOJ cross-price elasticity estimate for the FCOJ odds is positive and significant at 1.136, indicating a substitute relationship. On the other hand, the FCOJ cross-price elasticity for the RTSOJ equation is insignificant.

The positive and significant lag estimates indicate habit effects dominate inventory effects (Tilley, p. 42; Sexauer, p. 130). The coefficient estimates for the lagged variables also indicate the long-run price and income elasticity estimates for the FCOJ, RTSOJ and FCOJ-RTSOJ odds are 2.23, 2.29 and 1.69 times greater, respectively, than the corresponding short-run elasticity estimates. Ninety-five percent of the long-run effect occurs in five months for the FCOJ and RTSOJ odds equations. For the FCOJ-RTSOJ odds equation, only three months are required for ninety-five percent of the long-run effect to occur. The results show that the stronger the habit effect, the longer the time period for the ninety-five percent long-run adjustment to occur. Strong habits imply price and income effects are less fully felt in the short run.

In addition to directly indicating odds relationships for purchasing orange juice, the coefficients in Table 1 can also be applied to given explanatory variable values to estimate the purchase probabilities defined in equation 1. The transformation to purchase probabilities allows direct analysis of how changes in the explanatory variables impact market participation. The latter might be more useful in the development and evaluation of marketing strategies.

The results of the study are not directly comparable to findings reported elsewhere, although related findings are reported by Tilley. Tilley used double logarithmic equations to estimate demand relationships for the percent of families buying FCOJ and chilled orange juice (COJ) employing monthly data from January 1972 through January 1979. COJ is the dominant form of RTSOJ. The relationships for FCOJ and COJ were estimated separately and not as part of a probability model, in contrast to the present study. Nevertheless, Tilley found that both own-price elasticities were negative with the

FCOJ price elasticity larger than that for COJ. In the present study, the own-price elasticity for the FCOJ odds was also found to exceed that for the RTSOJ odds. The cross-price effects were insignificant in the Tilley study, whereas, in the present study, the RTSOJ price was found to positively affect the FCOJ odds. In both studies, income was found to positively affect the COJ or RTSOJ choice while not significantly affecting the FCOJ choice. On the other hand, although both studies found habits positively affecting the COJ or RTSOJ choice, Tilley found a negative inventory effect for the FCOJ choice, in contrast to the findings presented in this study. The latter may be related to different data employed as well as different modeling approaches used. Substantial changes in the orange juice market have occurred since the Tilley study. This alone would suggest differences in the findings. The differences may also be related to the use of more precise probability relationships in the present study.

Concluding Comments

Market participation is an important factor underlying the demand for orange juice and, in particular, the major product forms of orange juice -- FCOJ and RTSOJ. Application of the multinomial logit model to frequency data on number of households purchasing the different forms of orange juice indicates seasonality, income, prices, and habits are important factors in the household choice of product form. The odds of choosing FCOJ, RTSOJ or FCOJ-RTSOJ relative to the choice of not consuming orange juice were estimated to decrease in the summer by 7%, 3%, and 8%, respectively. The income elasticity estimates for the RTSOJ odds and the FCOJ-RTSOJ odds are both slightly over 1 while income does not significantly affect the FCOJ odds. The own-price elasticity estimates for the FCOJ odds and the RTSOJ odds are -1 and -.7, respectively. The price elasticity estimates for the FCOJ-RTSOJ odds were negative but insignificant. The cross-price estimates suggest the FCOJ odds are positively affected by the RTSOJ price while the RTSOJ odds are neutral with respect to the FCOJ price. The odds in the previous period were estimated to positively affect the present odds for all three choices, suggesting the presence of consumer habits in purchasing orange juice.

The analysis in this study offers more evidence about the importance of market participation for orange juice. With the development of probability models such as the multinomial logit model and the availability of frequency data, estimating market participation relationships has the potential to become an important part of market analysis. An area where the model might be useful is in the development of advertising and promotion programs. Incorporation of advertising/promotion program variables into the model would enable evaluation of the sensitivity of market participation and might be useful in determining relative program weights for attracting new buyers and increasing the demands of repeat buyers. The advertising/promotion program variables could include measures of program expenditures on different types of promotion as well as demographic variables useful in targeting consumer groups.

Table 1. Multinomial Logit Estimates for the Log Odds of Purchasing FCOJ, RTSOJ, and Both FCOJ and RTSOJ, Relative to Nonconsumption of Orange Juice, Based on the Parks Model, December 1977 to August 1986

Independent Variable[b]	Dependent Variable[a]		
	FCOJ	RTSOJ	FCOJ-RTSOJ
Constant	.541[c] (3.478)[d]	-13.461 (3.567)	-11.878 (6.207)
Summer	-.068 (.016)	-.028 (.014)	-.084 (.028)
Income	-.111 (.272)	1.225 (.289)	1.051 (.482)
FCOJ Price	-1.039 (.228)	.071 (.194)	-.443 (.387)
RTSOJ Price	1.136 (.221)	-.730 (.218)	-.281 (.383)
Lag	.551 (.062)	.564 (.064)	.409 (.075)

[a] FCOJ, RTSOJ and FCOJ-RTSOJ are the logarithms of the odds of purchasing only FCOJ, only RTSOJ, and both FCOJ and RTSOJ relative to nonconsumption of orange juice, respectively.

[b] Summer = 1 for May through August, zero otherwise.
Income = logarithm of deflated per capita income.
FCOJ Price = logarithm of the deflated price of FCOJ.
RTSOJ Price = logarithm of the deflated price of RTSOJ.
Lag = the lagged dependent variable.

[c] Coefficient estimate.

[d] Asymptotic standard error estimate.

Table 2. Sample Means and Selected Data on Choice Frequencies and Odds Ratios for Alternative Orange Juice Products

Year	Choice Category: Nonconsumption of Orange Juice		FCOJ		RTSOJ		FCOJ-RTSOJ	
	Freq.[a]	Odds[b]	Freq.	Odds	Freq.	Odds	Freq.	Odds
1978	.578	1.000	.300	.519	.090	.156	.032	.055
1981	.566	1.000	.284	.502	.113	.200	.038	.067
1985	.566	1.000	.233	.412	.155	.274	.047	.083
Mean[c]	.565	1.000	.271	.480	.124	.219	.040	.071

[a] Monthly average household choice frequency, $f_i = \frac{n_i}{\Sigma n_i}$, where n_i is the number of households selecting category i.

[b] Odds of the choice relative to the choice of nonconsumption of orange juice based on monthly frequency averages.

[c] For December 1977 through August 1986.

Appendix A

Ordinary Least Squares Estimates for the Log Odds of Purchasing FCOJ, RTSOJ, and Both FCOJ and RTSOJ, Relative to Nonconsumption of Orange Juice, December 1977 to August 1986

Independent Variable[b]	Dependent Variable[a]		
	FCOJ	RTSOJ	FCOJ-RTSOJ
Constant	2.029[c] (3.502)[d]	-13.024 (3.716)	-13.985 (6.259)
Summer	-.081 (.017)	-.028 (.014)	-.094 (.029)
Income	-.249 (.274)	1.191 (.304)	1.241 (.488)
FCOJ Price	-1.180 (.232)	.050 (.196)	-.314 (.390)
RTSOJ Price	1.319 (.229)	-.707 (.229)	-.566 (.396)
Lag	.421 (.074)	.574 (.073)	.262 (.095)
R^2	.73	.92	.61
Durbin h Statistics	.72	.86	1.16

[a] FCOJ, RTSOJ, and FCOJ-RTSOJ are the logarithms of the odds of purchasing only FCOJ, only RTSOJ, and both FCOJ and RTSOJ relative to nonconsumption of orange juice, respectively.

[b] Summer = 1 for May through August, zero otherwise.
Income = logarithm of deflated per capita income.
FCOJ Price = logarithm of the deflated price of FCOJ.
RTSOJ Price = logarithm of the deflated price of RTSOJ.
Lag = the lagged dependent variable.

[c] Coefficient estimate.

[d] Standard error estimate.

Appendix B

Multinomial Logit Estimates for the Log Odds of Purchasing FCOJ, RTSOJ, and both FCOJ and RTSOJ, Relative to Nonconsumption of Orange Juice, Based on the Traditional Model, December 1977 to August 1986

Independent Variable[b]	Dependent Variable[a]		
	FCOJ	RTSOJ	FCOJ-RTSOJ
Constant	.603[c] (1.396,3.494)[d]	-11.784 (2.123,3.626)	-13.400 (2.982,6.257)
Summer	-.078 (.007,.017)	-.025 (.008,.014)	-.102 (.014,.029)
Income	-.129 (.109,.273)	1.062 (.172,.294)	1.192 (.231,.487)
FCOJ Price	-1.196 (.092,.230)	.072 (.110,.195)	-.394 (.179,.391)
RTSOJ Price	1.313 (.091,.225)	-.616 (.129,.222)	-.449 (.185,.392)
Lag	.464 (.028,.068)	.627 (.041,.067)	.307 (.045,.087)

a FCOJ, RTSOJ, and FCOJ-RTSOJ are the logarithms of the odds of purchasing only FCOJ, only RTSOJ, and both FCOJ and RTSOJ relative to nonconsumption of orange juice, respectively.

b Summer = 1 for May through August, zero otherwise.
Income = logarithm of deflated per capita income.
FCOJ Price = logarithm of the deflated price of FCOJ.
RTSOJ Price = logarithm of the deflated price of RTSOJ.
Lag = the lagged dependent variable.

c Coefficient estimate.

d Asymptotic standard error estimate: first entry is based on the traditional model error structure; second entry is based on the Parks model error structure (for discussion, see Parks).

References

Amemiya T. "Qualitative Response Models: A Survey." J. Econ. Lit., XIX(1981):1483-1536.

Anemiya, T. "Tobit Models: A Survey." J. Econometrics, 24(1984): 3-61.

Anemiya, T. and F. Nold. "A Modified Logit Model." Rev. Econ. Stat., 57(1975):255-257.

Bewely, R. Allocation Models: Specificiation, Estimation and Applications. Cambridge MA: Ballinger Publishing Co., 1986.

Bewely, R. and T. Young. "Applying Theil's Multinomial Extension of the Linear Logit Model to Meat Expenditure Data." Amer. J. Agr. Econ., 69(1987):151-157.

Brown, M. G. "The Demand for Fruit Juices: Market Participation and Quantity Demanded." West. J. Agr. Econ., 11(1986):179-183.

Considine, T. J. and T. D. Mount. "The Use of Linear Logit Models for Dynamic Input Demand Systems." Rev. Econ. Stat., 56(1984):434-43.

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

Jackson, L. F. "Hierarchic Demand and the Engle Curve for Variety." Rev. Econ. Stat., 66(1984):8-15.

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.

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

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

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.

Nielsen Co. Data provided to the Florida Department of Citrus, Lakeland, Florida.

NPD Research, Inc. "Market Summary of the Beverage Category." Prepared for the Florida Department of Citrus, Dec. 1977 through Aug. 1986, Flora Park, New York.

Parks, R. W. "On Estimation of Multinomial Logit Models From Relative Frequency Data." J. Econ., 13(1980):293-303.

Sexauer, B. "The Role of Habits and Stocks in Consumer Expenditure." Qtr. J. Econ., 91(1977):127-142.

Stacy, J. "A New Perspective on Fruit Juices." Beverage World, (July 1987):59-64.

Theil, H. "On the Estimation of Relationships Involving Qualitative Variables." Amer. J. Sociology, 76(1970):103-154.

Theil, H.. Principles of Econometrics. New York: John Wiley and Sons, 1971.

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." So. J. Agr. Econ. 11,2(1979):41-46.

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

Tyrrell, T. and T. D. Mount. "A Nonlinear Expenditure System Using a Linear Logit Specification." Amer. J. Agr. Econ., 64(1982):539-45.

U. S. Department of Commerce, Bureau of Economic Analysis. Survey of Current Business, selected issues.

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

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