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Adult Equivalent Scales Revisited

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ABSTRACT

Use of the Tobit model for estimation of adult equivalent scale (AES) parameters and expenditure equations presupposes that zero observations represent exclusively corner solutions. This paper tests for the underlying causes of zero observations and estimates accordingly the AES parameters, the household size in adult equivalents and the resulting expenditure equations and consumption profiles. The empirical application concerns Greek household "soft" and "hard" cheese consumption. The statistical results indicate that for the examined cheese categories the "double hurdle participation" model adjusted for non-normality and heteroskedasticity is the appropriate model for the estimation of AES parameters and expenditure equations.

Key Words: *adult equivalent scales, double-hurdle models, soft and hard cheese, Greece.*

Adult equivalent scales (AES) are widely used in household consumption analysis primarily because they are more meaningful than the indiscriminate "per-capita" consumption. AES can be stepwise discrete (Prais and Houthakker; Price), or continuous (Blokland; Buse and Salathe; Tedford, Capps and Havlicek). The stepwise discrete scales are characterized by constant values over the various periods of a person's life that change abruptly when the household member enters the next period of his/her life. The continuous scales address exactly this problem of discontinuity and hypothesize that changes in consumption behavior are smooth and continuous functions of every household member's biological and psychological growth.

The Tedford-Capps-Havlicek (TCH) model has been used extensively in recent studies for the calculation of continuous AES parameters (e.g. Gould, 1992 and 1994; Anderson and Senauer). Tedford, Capps and Havlicek used a nonlinear regression algorithm using Marquardt's compromise (Draper and Smith) to estimate the AES parameters. In 1992, Gould estimated dairy AES using a Tobit specification (Amemiya), which is nonlinear in the AES parameters. The underlying assumption in related studies is that zero observations on expenditures or consumption represent typical corner solutions. However, the presence of zero observations in cross-sectional micro data, a very common phenomenon especially when individual commodities are examined, could also be attributed to true non-consumption (because of taste and health concerns, for example) and to the infrequency of purchases (i.e., short duration of the survey period) (Pudney).

The objective of this paper is to explicitly consider the underlying causes of zero observations and to estimate the AES parameters accordingly, the household size in adult equivalents and the resulting expenditure equations and consumption profiles. The empirical application concerns Greek household cheese consumption (soft and hard cheese) using data from the 1993/94 National Household Budget

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Survey. Greek per-capita consumption of cheese, at 22 kg per year, is the highest in the EU and cheese expenditure by Greek households accounts for almost 50 percent of the "dairy products" category. This is the third most important food category after "meats" and "fruits and vegetables." Despite the importance of cheese in the Greek diet, 50.3 percent and 28.5 percent of households in the sample reported zero expenditure in the survey period for hard and soft cheese, respectively.

Since a large proportion of values of the dependent variables is clustered at zero, a straightforward application of OLS would have yielded biased and inconsistent estimates (Amemiya). Thus, the cheese AES parameters were estimated using the well-known limited dependent variable (LDV) models, adjusted for non-normality (with application of the Inverse Hyperbolic Sine, IHS, transformation) and heteroskedasticity (with parameterization of the standard deviation) of the error terms. More specifically, the AES parameters for hard and soft cheese were estimated using the following LDV models: a) "IHS double hurdle participation" (Yen, Jensen and Wang; Yen and Huang; Su and Yen; Yen and Jones), b) "IHS infrequency of purchase" (Su and Yen), and c) "IHS Tobit" (Reynold and Shonkwiler). In the process, the most appropriate model for the purpose at hand was selected using relevant statistical procedures. The TCH Adult Equivalent Scale, the model selection procedure and the basic characteristics of the dominant empirical model are presented in the next section. Section 3 presents and discusses the results of the econometric estimation. The soft and hard cheese expenditure equations and the accompanied consumption profiles are also presented in this section. The paper concludes with a synopsis of the major findings.

The TCH Adult Equivalent Scale

The TCH Adult Equivalent Scale is based on the assumption that a person's life cycle is a sequence of developmental and transitional periods (Levinson *et al*). The developmental periods (age periods 1–17, 23–40, 46–60, and 66–80) refer to the basic phases of a person's life. The transitional periods (age periods 0, 18–22, 41–45, 61–65 and >80) constitute times of reassessment and planning that link the developmental periods with each other, providing continuity to the changes which occur in the outgoing and incoming developmental phases, (Levinson *et al.*).

For the jth household member of age a_j and gender s_j, the AES value is given by:

$$(1) \quad \mathrm{AES}_j = S(a_j, s_j).$$

This function takes the value of 1 when the household member is male between the ages of 41 and 45 (reference household member). Cubic functions, i.e., continuous functions of age and gender, are used to estimate the equivalence scale values during the developmental periods. During the transitional periods this value remains constant (see Tedford Capps and Havlicek, p. 326). The number of adult equivalents in each household, which is usually called the "true" household size, is obtained by summing equations (1) over all household members. Household equivalent scales are aggregates of the adult equivalent scales and may be expressed as explicit functions of the adult scale parameters:

$$\begin{aligned}(2) \quad \mathrm{AES} = {} & \mathrm{M}_1{\cdot}\mathrm{VA} + \mathrm{M}_2{\cdot}\mathrm{VB} + \mathrm{M}_3{\cdot}\mathrm{VC} \\ & + \mathrm{M}_4{\cdot}\mathrm{VD} + \mathrm{M}_5{\cdot}\mathrm{VE} + \mathrm{F}_2{\cdot}\mathrm{VF} \\ & + \mathrm{F}_3{\cdot}\mathrm{VG} + \mathrm{F}_4{\cdot}\mathrm{VH} + \mathrm{F}_5{\cdot}\mathrm{VI} \\ & + \mathrm{E}_{11}{\cdot}\mathrm{VJ} + \mathrm{E}_{21}{\cdot}\mathrm{VK} + \mathrm{E}_{31}{\cdot}\mathrm{VL} \\ & + \mathrm{E}_{41}{\cdot}\mathrm{VM} + \mathrm{E}_{12}{\cdot}\mathrm{VN} + \mathrm{E}_{22}{\cdot}\mathrm{VO} \\ & + \mathrm{E}_{32}{\cdot}\mathrm{VP} + \mathrm{E}_{42}{\cdot}\mathrm{VQ},\end{aligned}$$

where, the variables VA through VQ represent 17 (age-gender dependent) weighted variables, (see Tedford Capps and Havlicek, p.333). The unknown parameters M_1, M_2, M_4, M_5, F_2, F_3, F_4 and F_5 measure in adult equivalents the effects of adding a member belonging in a transitional period to the household, relative to the reference household member ($M_3 = 1$). The parameters E_{11}, E_{21}, E_{31}, E_{41}, E_{12}, E_{22}, E_{32} and E_{42}, correspond to cubic functions for male and female developmental periods. The selection of the appropriate empirical model for the estimation of the above AES parameters and the characteristics of the selected model are presented in the following subsections.

Model Selection

The selection procedure involves two phases. First, a comparison between the two non-nested models, i.e., the "IHS double hurdle participation" and the "IHS infrequency of purchase" with a Vuong test (Vuong), is undertaken. The values of the test statistic for soft and hard cheese are 4.99 and 2.32, respectively, which are greater than the relevant critical value of 1.96, indicating that the appropriate model for both kinds of cheese is the IHS double hurdle participation. Second, a comparison between this model and the simple "IHS Tobit" with a LR test (Greene, 1990) is carried out. The values of the test statistic for soft and hard cheese are 431.64 and 180.0, respectively, which are greater than the critical value of the χ^2 distribution with 26 degrees of freedom (38.9). Therefore, the null hypothesis that there is no difference between the two nested models is rejected by the data and, consequently, the IHS double hurdle participation model is preferred. More details about the above tests can be found in the Appendix.

The IHS Double Hurdle Participation Model

The double hurdle participation model (Cragg) implies that a) zero observations represent corner solutions and/or true non-consumption, and b) the decision to participate in the market of a particular product and the decision on the level of consumption are two different processes. Thus, the model contains a "selection" and an "outcome" equation:

$$(3) \qquad Z_h^* = W_h\gamma + e_h \quad \text{(selection equation)},$$

where $e_h \sim N(0, 1)$

$$Y_h^* = X_h\beta + u_h \quad \text{(outcome equation)},$$

where $u_h \sim N(0, \sigma_u^2)$

where, the latent variables Z_h^* and Y_h^* represent the decision to participate in the market and the decision on the level of consumption, respectively. The latent variable Z_h^* represents the net effect of the various factors that influence the decision on whether to consume the product in question. If the difference is greater than zero ($Z_h^* > 0$) then the household participates in the market of the product. However, participation in the market does not necessarily imply positive expenditures. In other words, positive expenditures require further that $Y_h^* > 0$. In a different case, i.e., $Z_h^* > 0$ and $Y_h^* \leq 0$, the household participates in the market but it reports zero expenditures because the product price is high or the household income is low or both (typical corner solution). As a rule, the two sets of explanatory variables W_h and X_h include the same variables and it is assumed that they influence differently the decision to consume and the decision on the level of consumption (Yen and Huang). The same approach is followed in the present application and the variables included contain a) social and demographic dummy variables, b) total expenditures (a proxy for household income) and c) the household size in adult equivalents.

Based on the above, the relationship between the observed dependent variable Y_h and the latent variables is:

$$(4) \qquad Y_h = \begin{cases} Y_h^* = X_h\beta + u_h & \text{if } Z_h^* > 0 \text{ and } Y_h^* > 0, \\ 0 & \text{otherwise.} \end{cases}$$

To incorporate non-normality in (4), the IHS transformation of Y_h (Burbidge, Magee and Robb) is employed:

$$(5) \qquad T(Y_h) = \frac{\log[\Theta \cdot Y_h + (\Theta^2 Y_h^2 + 1)^{1/2}]}{\Theta} = \frac{\sinh^{-1}(\Theta Y_h)}{\Theta},$$

where, Θ is the non-normality parameter to be estimated. Since the transformed variable is symmetric about 0 in Θ, only $\Theta \geq 0$ will be considered. In order to estimate the coefficients of the variables in X_h and W_h and assuming independence between the errors of the selection and outcome equations, the log-likelihood of the "IHS double hurdle participation" model (Su and Yen, p. 517) is used:

$$(6)\quad \log L = \sum_0 \log\left[1 - \Phi\left(\frac{X_h\beta}{\sigma_u}\right)\Phi(W_h a)\right] + \sum_+ \left[-\log \sigma_h + \log \varphi\left(\frac{T(Y_h) - X_h\beta}{\sigma_u}\right) + \log \Phi(W_h a) - \frac{1}{2}\log(1 + \Theta^2 Y_h^2)\right],$$

where, Σ_0 and Σ_+ refer to summations over zero and positive observations for Y_h and $\Phi(\cdot)$ and $\varphi(\cdot)$ refer to the standard normal cumulative and density functions, respectively. The term $\Phi(X_h\beta/\sigma_u)$ represents the probability of a non-zero observation and the term $\Phi(W_h a)$ represents the probability of participation in the market. The product $\Phi(X_h\beta/\sigma_u)\Phi(W_h a)$ represents the probability of observing positive expenditure and, thus, its complement probability, i.e., $1 - \Phi(X_h\beta/\sigma_u)\Phi(W_h a)$ represents the probability of zero expenditure.

Finally, to incorporate heteroskedasticity into (6) the parameterization of the standard deviation is applied (Godfrey):

$$(7)\quad \sigma_u = \exp(D_h \cdot \xi),$$

where, D_h is a row vector of exogenous variables and ξ is a column parameter vector. The explanatory variables in D_h are a) social and demographic dummy variables and b) total expenditures by the hth household. It should be noticed that if the probability of participation in the market is $\Phi(W_h a) = 1$, then the log-likelihood (6) reduces to the log-likelihood corresponding to the "IHS Tobit" model.

Descriptive Statisitics

The data used for the estimation of the empirical models are derived from the 1993/94 National Household Budget Survey, which contains detailed information for 6751 households. The duration of the reference period was two weeks and expenditure data were collected for a large number of food and non-food items. Cheese expenditure data refer to cheese aggregates, i.e., "soft" and "hard" cheese, and, therefore, some of the observed cheese expediture variability might be attributed to quality differences. This is a valid argument especially for "hard" cheese that includes more than a dozen kinds of hard cheeses. The case of "soft" cheese is less problematic since this category is dominated by "feta cheese," a traditional Greek cheese. In any event, the use of expenditure data instead of quantity data is the rule and not the exception in most similar studies (Gould, 1992, Yen and Su).

Table 1 presents the descriptive statistics of the basic variables. On average cheese-consuming households have higher total expenditures than non-consuming ones, hard-cheese-consuming households have higher total expenditures than soft-cheese-consuming ones, and the average number of persons per household for the full sample is 2.94, for soft-cheese-consuming households is 3.09 and for hard-cheese-consuming households is 3.21. Furthermore, a) 76.3 percent of hard-cheese-consuming households live in urban centers and 23.7 percent in rural areas, b) 46.4 percent of hard-cheese non-consuming households have a meal planner older than 55 years, and c) the consumption of both soft and hard cheese is, for all practical purposes, equally distributed in the four seasons.

Estimation Results

The econometric software LIMDEP 7 was used to maximize the log-likelihood function of the dominant "IHS double hurdle participation" model (Greene, 1997). Table 2 presents the estimates of the adult scale parameters, equation (2), M_1, M_2, M_4, M_5, F_2, F_3, F_4, F_5, E_{11}, E_{21}, E_{31}, E_{41}, E_{12}, E_{22}, E_{32} and E_{42}, relative to the parameter $M_3(=1)$ for both, hard and soft cheese. Seven out of nine transitional coefficients and three out of eight developmental coefficients for soft cheese consumption are statistically significant. The estimated values of the coefficients M_4, M_5, F_2, F_3, F_4 and F_5 indicate that a male of age 61–65 and >80, and a female of age 18–22, 41–45, 61–

Table 1. Descriptive Sample Statistics

Variable	Full Sample	Soft Cheese: Consuming Households	Soft Cheese: Non-consuming Households	Hard Cheese: Consuming Households	Hard Cheese: Non-consuming Households
Soft cheese expenditures[a]	3764	5264	0	—	—
	(4508)[b]	(4531)			
Hard cheese expenditures[a]	1803	—	—	3624	0
	(2852)			(3122)	
Household size for soft cheese in Adult Equivalents	2.48	2.60	2.18	—	—
	(1.02)	(0.99)	(1.05)		
Household size for hard cheese in Adult Equivalents	2.70	—	—	3.01	2.41
	(1.43)			(1.33)	(1.46)
Household size in number of persons	2.94	3.09	2.57	3.21	2.68
	(1.38)	(1.36)	(1.36)	(1.32)	(1.39)
Total household expenditures[a]	343838	365100	290497	402868	285382
	(241709)	(245340)	(223687)	(257931)	(208676)
Dummy variables (yes = 1, no = 0)					
Urban household	0.700	0.688	0.732	0.763	0.639
Meal planner 35–55 years old	0.400	0.427	0.334	0.459	0.343
Meal planner >55 years old	0.381	0.366	0.419	0.298	0.464
Education of meal planner (6–9 years)	0.461	0.476	0.423	0.463	0.458
Education of meal planner (>9 years)	0.309	0.299	0.332	0.328	0.245
Meal planner not working	0.651	0.638	0.683	0.616	0.686
Meal planner working >35 hours per week	0.256	0.264	0.234	0.279	0.232
Summer	0.244	0.246	0.235	0.230	0.257
Autumn	0.245	0.255	0.222	0.252	0.239
Winter	0.253	0.251	0.260	0.270	0.237
Sample size	6751 (100%)	4827 (71.5%)	1924 (28.5%)	3359 (49.8%)	3392 (50.2%)

[a] Monthly expenditures in Greek drachmas.
[b] Standard deviations in parentheses.
Source: National Household Budget Survey 1993/94, National Statistical Service of Greece, Athens, 1996.

Table 2. Estimates of Adult Equivalent Scale Parameters using the Inverse Hyperbolic Sine Double Hurdle Participation Model for Soft and Hard Cheese in Greece

Variable	Coefficient	Soft Cheese	Hard Cheese
VA (Transitional period: M[1] & F[2] 0 years old)	M_1	0.080	−0.200
		(0.269)	(0.602)
VB (Transitional period: M 18–22 years old)	M_2	0.012	0.066
		(0.079)	(0.020)
VC (Transitional period: M 41–45 years old)	M_3	1.000***	1.000**
		(0.169)	(0.468)
VD (Transitional period: M 61–65 years old)	M_4	1.325***	0.889**
		(0.163)	(0.384)
VE (Transitional period: M >80 years old)	M_5	1.105***	0.375
		(0.192)	(0.506)
VF (Transitional period: F 18–22 years old)	F_2	0.437***	0.342*
		(0.087)	(0.200)
VG (Transitional period: F 41–45 years old)	F_3	1.494***	1.694***
		(0.221)	(0.509)
VH (Transitional period: F 61–65 years old)	F_4	0.835***	1.050**
		(0.194)	(0.485)
VI (Transitional period: F >80 years old)	F_5	0.611***	0.102
		(0.167)	(0.413)
VJ (Developmental period: M 0–17 years old)	E_{11}	0.051	0.254
		(0.099)	(0.209)
VK (Developmental period: M 23–40 years old)	E_{21}	0.256***	−0.076
		(0.060)	(0.136)
VL (Developmental period: M 46–60 years old)	E_{31}	0.211***	0.400**
		(0.080)	(0.172)
VM (Developmental period: M 66–80 years old)	E_{41}	−0.074	−0.181
		(0.087)	(0.223)
VN (Developmental period: F 0–17 years old)	E_{12}	0.043	0.331
		(0.099)	(0.206)
VO (Developmental period: F 23–40 years old)	E_{22}	0.140**	0.314*
		(0.070)	(0.164)
VP (Developmental period: F 46–60 years old)	E_{32}	−0.070	0.497**
		(0.084)	(0.202)
VQ (Developmental period: F 66–80 years old)	E_{42}	0.027	0.109
		(0.082)	(0.200)

[1] Male.
[2] Female.
One, two and three asterisks indicate statistical significance at the 10%, 5% and 1% level, respectively. The numbers in parentheses are standard errors. The variables VA through VQ are weighted sum variables, dependent on the age-sex composition of the household (see Tedford, Capps and Havlicek, p. 333).

65 and >80 spend 32.5 percent more, 10.5 percent more, 56.3 percent less, 49.4 percent more, 16.5 percent less and 38.9 percent less on soft cheese than the "reference member," respectively. The results for hard cheese show that five out of nine transitional coefficients and three out of eight developmental coefficients are statistically significant. The estimated values of the transitional coefficients M_4, F_2, F_3 and F_4 indicate that a male of age 61–65, and a female of age 18–22, 41–45 and 61–65, spend 11.1 percent less, 65.8 percent less, 69.4 percent more and 5 percent more on hard cheese than the "reference member," respectively.

Using the estimated AES parameters and the AES functions $S(a_j, s_j)$, the male and female soft and hard cheese consumption pro-

Figure 1. Adult Equivalent Profiles for Soft Cheese Expenditures in Greece (Inverse Hyperbolic Sine Double Hurdle Participation Model)

files are calculated (Figures 1 and 2). The female profile for soft cheese lies above the male one up to age 47 while for hard cheese up to age 77. Furthermore, soft cheese consumption by males reaches a maximum at the age of 50 and for women at the 41–45 age class. For hard cheese, both sexes reach maximum consumption at 50.

Using equation (2) and replacing the parameters M_1, M_2, M_4, M_5, F_2, F_3, F_4, F_5, E_{11}, E_{21}, E_{31}, E_{41}, E_{12}, E_{22}, E_{32} and E_{42} with their estimated values (Table 2), the "true" household size for soft and hard cheese can be calculated. The average "true" household size for soft cheese consumption is 2.48 (see Table 1) and for hard cheese is 2.70 adult equivalents. In addition, soft-cheese-consuming households contain, on average, 2.6 adult equivalents and hard-cheese-consuming households contain 3.01 adult equivalents. It is evident that the difference in the estimated household size in adult equivalence terms and in number of persons is substantial.

Table 3 presents the results of estimation of

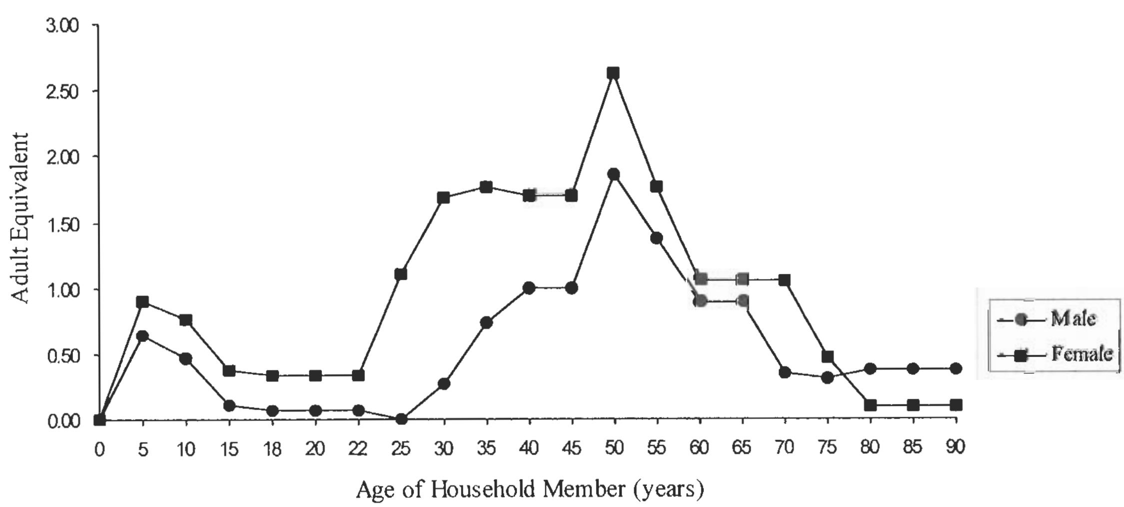

Figure 2. Adult Equivalent Profiles for Hard Cheese Expenditures in Greece (Inverse Hyperbolic Sine Double Hurdle Participation Model)

Table 3. Parameter Estimates of the Inverse Hyperbolic Sine Double Hurdle Participation Model for Soft and Hard Cheese in Greece

Variable	Soft Cheese: Selection Equation	Soft Cheese: Outcome Equation	Hard Cheese: Selection Equation	Hard Cheese: Outcome Equation
Intercept	1.830***	−0.003	2.024***	−0.390***
	(0.425)	(0.034)	(0.746)	(0.021)
Adult Equivalent Scale	0.093***	0.068***	0.065**	0.041***
	(0.025)	(0.005)	(0.025)	(0.005)
Total Household Expenditures	0.703***	0.135***	1.070***	0.193***
	(0.098)	(0.016)	(0.121)	(0.023)
Urban Household	−0.153***	−0.042***	0.235***	0.031
	(0.053)	(0.009)	(0.082)	(0.021)
Meal Planner 35–55 years old	−0.113	0.036***	−0.265**	0.030
	(0.073)	(0.012)	(0.105)	(0.023)
Meal Planner >55 years old	−0.139*	0.050***	−0.402***	0.074***
	(0.079)	(0.013)	(0.118)	(0.027)
Education of Meal Planner (6–9 years)	−0.125*	0.037***	−0.484***	0.162***
	(0.069)	(0.012)	(0.177)	(0.033)
Education of Meal Planner (>9 years)	−0.331***	0.018	−0.424**	0.175***
	(0.082)	(0.013)	(0.187)	(0.034)
Meal Planner not working	−1.213***	0.089***	−1.614**	0.173***
	(0.412)	(0.023)	(0.647)	(0.022)
Meal Planner working >35 hours per week	−1.159***	0.105***	−1.630**	0.173***
	(0.412)	(0.024)	(0.647)	(0.022)
Summer	−0.020	0.054***	−0.250**	0.057***
	(0.065)	(0.012)	(0.102)	(0.020)
Autumn	−0.079	0.008	−0.110	0.053***
	(0.066)	(0.011)	(0.103)	(0.020)
Winter	−0.063	0.009	−0.129	0.067***
	(0.065)	(0.011)	(0.103)	(0.020)
Non-normality parameter Θ	2.473***		2.779***	
	(0.156)		(0.248)	

Notes: One, two and three asterisks indicate statistical significance at the 10%, 5% and 1% level, respectively. The numbers in parentheses are standard errors.

Table 4. Elasticities with Respect to Continuous Variables: Soft and Hard Cheese Consumption by Greek Households

	Soft Cheese			Hard Cheese		
Variable	Probability	Conditional	Unconditional	Probability	Conditional	Unconditional
Household size (in Adult Equivalents)	0.221*** (0.058)	0.352*** (0.026)	0.573*** (0.071)	0.343** (0.131)	0.350*** (0.043)	0.693*** (0.145)
Total Household Expenditures	0.102*** (0.014)	0.030*** (0.004)	0.132*** (0.016)	0.260*** (0.029)	0.191*** (0.023)	0.451*** (0.041)

Notes: Two and three asterisks indicate statistical significance at the 5% and 1% level, respectively. The numbers in parentheses are standard errors.

the selection and the outcome equations for both soft and hard cheese. The decision to participate in the consumption of soft cheese is influenced positively by household size (in adult equivalents) and total household expenditures and negatively by urbanization and the presence in the household of a meal planner a) older than 55 years, b) with more than six years of schooling, and, c) working more than 35 hours per week or not working at all. With regard to the level of soft cheese consumption the following points are worth making: household size, total expenditures and the presence of a meal planner a) older than 35 years, b) with 6–9 years of schooling, and, c) working more than 35 hours per week or not working at all influence positively the consumption of soft cheese. In addition, soft cheese consumption appears increased in the summertime.

The IHS transformation and the heteroskedastic error specification make the decomposition of total effect of independent variables especially important. The unconditional mean of the dependent variable Y_h (Karlin and Taylor) is

$$(8)\quad E(Y_h) = pr(Y_h > 0)\cdot E(Y_h \mid Y_h > 0) = E(Y_h \mid Y_h > 0)\cdot \Phi(W_h a)\cdot \Phi\left(\frac{X_h\beta}{\sigma_u}\right),$$

where, the probability of a positive observation (Su and Yen) is

$$(9)\quad pr(Y_h > 0) = pr(Z_h^* > 0)\cdot pr(Y_h^* > 0) = \Phi(W_h a)\cdot \Phi\left(\frac{X_h\beta}{\sigma_u}\right)$$

and the conditional mean of Y_h is

$$(10)\quad E(Y_h \mid Y_h > 0) = \left[\Phi\left(\frac{X_h\beta}{\sigma_u}\right)\right]^{-1} \int_0^\infty Y_h \cdot \frac{1}{\sigma_u}(1 + \Theta^2\cdot Y_h^2)^{-1/2} \cdot \varphi\left(\frac{T(Y_h) - X_h\beta}{\sigma_u}\right) dY_h.$$

In order to derive the marginal effects and to calculate the probability elasticity and the unconditional and conditional elasticities, equations (8), (9) and (10) are differentiated with respect to the independent variable of interest. These elasticities with respect to AES and Total Household Expenditures are presented in Table 4.

The probability elasticity of the AES variable is 0.22, indicating that an increase in the household size by one adult equivalent will increase the probability of soft cheese household consumption by 22 percent. Furthermore, the conditional AES elasticity is 0.35, indicating that, given the participation of the household in the consumption of soft cheese, an increase in the household size by one adult equivalent will increase the consumption level by 35 percent. Finally, the conditional expenditure elasticity for soft cheese is very close to zero (0.03), indicating that further increases in expenditures (or income) will not result in significant consumption increases by consuming households. Similarly, the probability elasticity of total expenditures is also small, 0.10, indicating that large increases in expenditures (or incomes) are necessary to increase the number of soft cheese consuming households in Greece. These latter findings have important implications for Greek soft cheese producers and especially those producing the traditional and widely known "feta" cheese.

The results for the hard cheese selection and outcome equations are interpreted in a similar fashion. Nevertheless, the following points are worth making: a) "true" household size affects positively the probability and the level of hard cheese consumption, b) urbanization influences positively the probability of participation, c) the conditional expenditure elasticity is 0.19, almost six times higher than that for soft cheese, and d) the probability expenditure elasticity is 0.26, indicating that as income grows a greater number of households will enter the hard cheese market, in relation to the soft cheese one.

Finally, the non-normality parameter Θ is statistically significant in both soft and hard cheese equations, a significance that justifies the Inverse Hyperbolic Sine transformation of the double hurdle participation model. Furthermore, all the parameters of equation 7 are statistically significant, indicating the presence of heteroskedasticity, a presence that justifies the parameterization of the σ_u term.

Synopsis

The objectives of this paper were to estimate a) AES parameters by explicitly taken into consideration the underlying causes of zero observations, b) the true household size in adult equivalence terms and c) the resulting expenditure equations and consumption profiles. The empirical application concerned Greek household consumption of soft and hard cheese, two very important commodities of the Greek diet. It should be noted, however, that the developed methodology is not commodity specific and can be applied to every item in the food basket. The cross sectional data used for estimation purposes were drawn from the 1993/94 National Household Budget Survey.

The results of the statistical testing and analysis indicated that zero expenditures, a very common phenomenon in cross-sectional studies, can also be attributed to non participation and infrequent purchases and, therefore, "double hurdle" models are more appropriate than the simple Tobit model for the estimation of AES parameters. For the specific application, the double hurdle participation model, adjusted for non-normality and heteroskedasticity, proved to be the appropriate one. The estimation results show that indeed "true" household size varies significantly, depending on the model used. Therefore, the practice of using simple Tobit models indiscriminately is obviously not appropriate. For example, the "true" household sizes for soft and hard cheese are 2.33 and 2.13, respectively, when the Tobit model is used and 2.48 and 2.70 when the appropriate, i.e., suggested by the data at hand, double hurdle participation model is employed. It is obvious that these significant differences influence forecasts of soft and hard cheese consumption.

The results also indicated that the number of adult equivalents in the household influences the participation decision and the consumption level of both types of cheese. In addition, further increases in the income of Greek households are expected to increase the consumption of the hard cheese group, composed mostly of imported cheeses from other European countries. On the other hand, the consumption of domestically produced soft cheeses appears to be stable and further income increases are expected to raise only slightly the number of consuming households and the level of consumption. Finally, the estimated consumption profiles indicate that women consume more hard cheese than men and the same holds for soft cheese consumption up to age 47. The obtained results have important implications for food policy analysts, producers of traditional soft and hard cheeses in Greece and in the European Union, marketers of dairy products and, of course, dairy policy analysis in the CAP framework.

References

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

Anderson, M. and B. Senauer. "Non-Purchasing Households in Food Expenditure Survey: An Analysis for Potatoes in Sweden." Staff Paper P 94-4, University of Minnesota, 1994.

Blisard, N. and Blaylock, J. "Distinguishing Between Market Participation and Infrequency of Purchase Models of Butter Demand." *American Journal of Agricultural Economics* 75 (May 1993): 314–320.

Blokland, J. *Continuous Consumer Equivalence Scales.* The Hague: Martinas Nijhoff, 1976.

Burbidge, J., L. Magee and A. Robb. "Alternative Transformations to Handle Extreme Values of the Dependent Variable." *Journal of American Statistical Association* 83(1988): 123–127.

Buse, R. and L. Salathe. "Adult Equivalence Scales: An Alternative Approach." *American Journal of Agricultural Economics* 60(1978): 460–468.

Cragg, J. "Some Statistical Models for Limited Dependent Variables with Applications to the Demand for Durable Goods." *Econometrica* 39(1971): 829–844.

Draper, N. and H. Smith. *Applied Regression Analysis.* John Wiley & Sons, New York, 1966.

Godfrey, L. "Testing Against General Autoregressive and Moving Average Error Models When the Regressors Include Lagged Dependent Variables." *Econometrica* 46(1978b): 1293–1302.

Gould, B. "The Demand for Cheese in the United States: The Role of Household Composition." *Agribusiness* 10(1994): 43–59.

Gould, B. "At Home Consumption of Cheese: A Purchase-Infrequency Model." *American Journal of Agricultural Economics* 74(1992): 453–459.

Greene, W. *LIMDEP User's Manual and Reference Guide, Version 7.0.* New York: Econometric Software, 1997.

Greene, W. *Econometric Analysis.* New York: McMillan Publishing Co., 1990.

Karlin, S. and H. Taylor. *A First Course in Stochastic Processes, Vol. 1.* New York: Academic Press, 1975.

Levinson, D., C. Darrow, E. Klein, M. Levinson and B. Mckee. *The Seasons of a Man's Life.* New York: Ballantine Book, 1978.

National Statistical Service of Greece (NSSG). Household Expenditures Survey 1993–1994. Athens, 1996.

Prais, S. and H. Houthakker. *The Analysis of Family Budgets.* Cambridge: Cambridge University Press, 1955.

Price, D. "Unit Equivalence Scales for Specific Food Commodities." *American Journal of Agricultural Economics* 52(1971): 224–233.

Pudney, S. *Modeling Individual Choice, the Econometrics of Corners, Kinks and Holes.* New York: Basic Blackwell Inc., 1989.

Reynolds, A. and J. Shonkwiler. "Testing and Correcting for Distributional Misspecifications in the Tobit Model: An Application of the Information Matrix Test." *Empirical Economics* 16(1991): 313–323.

Su, S. and S. Yen. "Microeconometric Models of Infrequently Purchased Goods: An Application to Household Pork Consumption." *Empirical Economics* 21(1996): 513–533.

Tedford, J., O. Capps and J. Havlicek. "Adult Equivalent Scales Once More—A Developmental Approach." *American Journal of Agricultural Economics* 68(1986): 322–333.

Vuong, Q. "Likelihood Ratio Test for Model Selection and Non-Nested Hypotheses." *Econometrica* 57(1989): 307–333.

Yen, S. and C. Huang. "Household Demand for Finfish: A Generalized Double-Hurdle Model." *Journal of Agricultural and Resource Economics* 21(1996): 220–234.

Yen, S., H. Jensen and Q. Wang. "Cholesterol Information and Egg Consumption in the U.S.: A Nonnormal and Heteroscedastic Double-Hurdle Model." *European Review of Agricultural Economics* 23(1996): 343–356.

Yen, S. and A. Jones. "Household Consumption of Cheese: An Inverse Hyperbolic Sine Double-Hurdle Model with Depended Errors." *American Journal of Agricultural Economics* 79(1997): 246–251.

Appendix

The Vuong specification test is employed to suggest the appropriate model between the two non-nested models. Given a function $m(Y_h | W_h, \alpha)$, for the "IHS double hurdle participation" model and another function $f(Y_h | Q_h, \gamma)$, for the "IHS infrequency of purchase" model, the variance of the difference between the two likelihood functions is given (Vuong; Blisard and Blaylock) by:

$$\omega^2 \equiv \frac{1}{n}\sum_{h=1}^{n}\left[\log\frac{m(Y_h | W_h, \hat{\alpha})}{f(Y_h | Q_h, \hat{\gamma})}\right]^2 - \left[\frac{1}{n}\sum_{h=1}^{n}\log\frac{m(Y_h | W_h, \hat{\alpha})}{f(Y_h | Q_h, \hat{\gamma})}\right]^2$$

Three competing hypotheses are tested. The first is that both models are equivalent:

$$H_0: \quad E\left[\log\frac{m(Y_h | W_h, \alpha)}{f(Y_h | Q_h, \gamma)}\right] = 0.$$

This hypothesis is tested against

$$H_m: \quad E\left[\log\frac{m(Y_h|W_h, \alpha)}{f(Y_h|Q_h, \gamma)}\right] > 0$$

meaning that function m is preferred to f or

$$H_f: \quad E\left[\log\frac{m(Y_h|W_h, \alpha)}{f(Y_h|Q_h, \gamma)}\right] < 0$$

implying that function m is not preferred to f. The test statistic is:

$$\Lambda = n^{-1/2}\cdot\omega^{-1}\sum_{h=1}^{n}\log\frac{m(Y_h|W_h, \hat{\alpha})}{f(Y_h|Q_h, \hat{\gamma})}$$

If $\Lambda > C_{a/2}$, where $C_{a/2}$ is the critical value of the standard normal distribution, then the "IHS double hurdle participation" model is preferred to the "IHS infrequency of purchase" model, whereas if $\Lambda < -C_{a/2}$, the reverse holds. When $|\Lambda| \leq C_{a/2}$, then there is no difference between the two models.

A likelihood ratio-test is employed to test the hypothesis of equivalence between the "IHS Tobit" model and either one of the two non-nested models and it is given (Greene, 1990, p.388) by:

$$\begin{aligned} LR = &-2[\log L(\text{IHS Tobit}) \\ &- \log L(\text{IHS non-nested})] \end{aligned}$$

Under the null hypothesis, LR is distributed asymptotically as a χ^2 with degrees of freedom equal to the number of the right hand side variables in the "IHS Tobit" model, including the intercept. If the sample value exceeds the critical value of χ^2, then the hypothesis of equivalence is rejected.