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Incorporating Demographic Information in an Almost Ideal Demand System

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ABSTRACT

Information on household size, age, and sex of the U.S. population is incorporated into the Almost Ideal Demand System through adult equivalent scales. Estimates for an eleven and four commodity food system are compared with their per-capita counterparts. Inclusion of demographic information results in more theoretically and statistically consistent parameter estimates.

INTRODUCTION

The demographic characteristics of the U.S. population are continually changing. Since the 1950s, because of a declining birthrate and an increase in single headed households, average household size has decreased from 3.37 to 2.6 persons. At the same time, the population has been aging gradually, with a noticeable increase in the proportion of persons in the older age groups of the population distribution. Other factors including changes in regional population, racial mix, and female labor force participation rates have contributed to the dynamic flux of the population.

Household age-sex composition and size, regional population shifts, and racial mix have been shown to have an effect on food consumption overtime (Salathe; Blaylock and Smallwood; Buse and Salathe). Demographic characteristics change slowly over time, making it difficult to assess their impact on aggregate time series food consumption data. However, inclusion of demographic information in time series food and expenditure in time demand analysis has been limited to the incorporation of household size effects (Hayes, Wahl, and Williams) and changes in income distribution (Unnevehr; Eales and Unnevehr).

It is generally assumed in time series demand analysis that the per-capita data reflect the preferences of some representative consumer. Neoclassical consumer demand theory has addressed this issue by defining a class of cost functions in which the preferences of some representative consumer carry over consistently to a given community or population (Muellbauer). The Almost Ideal Demand System (AIDS) is derived from this class of cost functions. The AIDS model in its household form includes a demographic variable used to deflate a given household expenditures to some "needs corrected per-capita level" (Deaton and Muellbauer). The use of AIDS specifications which fail to model this demographic deflator implicitly assume that the preferences of some representative consumer can be rationalized by per-capita data.

This paper illustrates how demographic data can be incorporated into the Almost Ideal Demand System (AIDS). Population data on household size and age-sex composition is combined through use of adult equivalent scales to create an adult equivalent household AIDS model. The structural coefficients for a four commodity food demand system are estimated in both adult equivalent household and per-capita forms. The results from the comparison of the two specifications indicate that inclusion of demographic information results in more theoretically and statistically consistent parameter estimates.

The paper proceeds as follows. Following a discussion of the appropriateness of the inclusion of demographic information in the AIDS model, the adult equivalent household AIDS model is specified. Next, results from the estimation of the adult equivalent household and per-capita models are discussed. Concluding comments follow.

A DEMOGRAPHICALLY ENHANCED AIDS MODEL INCORPORATING HOUSEHOLD SIZE AND COMPOSITION

Following Ray (1982), the household utility function proposed by Barten is defined by:

$$U = U(z_1, z_2, \ldots, z_n) \qquad (1)$$

where $z_i = q_i/k_i$ denotes the family's per capita consumption of i, and where k_i, a demographic variable, is used as a deflator. The household utility function is maximized subject to a budget constraint to yield the household demand function:

$$z_i = z_i(p_1k_1, p_2k_2, \ldots, p_nk_n, x) \qquad i=1,\ldots,n \qquad (2)$$

where x is household income. Each of the prices are weighted by some demographic scale factor to arrive at normalized prices $p_i^* = p_i k_i$.

This same principle can be applied to the cost function to yield the household AIDS model, where the original price vector, p_i, is replaced by a normalized price vector, $p_i^* = p_i k_i$. The AIDS model for the individual household, h, is now defined

$$w_{ih} = \alpha_i + \Sigma_j g_{ij} \log p^*_j + \beta_i \log(x_h/P^*) \qquad (3)$$

where

$$\log P^* = \alpha_o + \Sigma_i \alpha_i \log p_i^* + 1/2 \Sigma\Sigma g_{ij} \log p_i^* \log p_j^* \qquad (4)$$

and x_h/P^* is per-capita real household expenditures and w_{ih} is the budget share of the i^{th} item used by the household. Because the formulation of the price index (4) makes the system of equations non-linear, Stone's price index,

$$\log P^* = \alpha_o + \Sigma_i w_i \log p_i^*, \qquad (5)$$

will be used as an approximation.

The scale factor k is defined as:

$$k = N^{\delta} \qquad (6)$$

where N is defined as the adult equivalent household size.

If $p_i k_i = p_i^*$ is substituted back into equation (3), it can be written for the representative household

$$w_{ih} = \alpha_i + \Sigma_j g_{ij} \log p_j + \beta_i \log x_h/P + \delta_i \log N \qquad (7)$$

where x_h/P denotes real total household expenditures. The adding up restrictions:

$$\Sigma_i \alpha_i = 1 \qquad \Sigma_i \beta_i = 0 \qquad \Sigma_i g_{ij} = 0 \qquad \Sigma_i \delta_i = 0$$

will automatically hold for the model. And, the

homogeneity $\quad \Sigma_j g_{ij} = 0$

and symmetry $\quad g_{ij} = g_{ji}$

restrictions can be imposed on the system or tested. In this analysis, the total food expenditures of the household were assumed to be weakly separable from total household non-food expenditures. Therefore, the same properties which hold for the AIDS specification applied to a choice set of household commodities hold for the system of food commodities.

Formulation of the Demographic Variable

In the two previous studies by Ray (1980, 1982) which utilize the above specification, N is defined as household size where the household size for the representative household in year t is average household size, or:

$$N_t = \frac{\text{Population}_t}{\#\text{ of households}_t}.$$

Ray notes that this form has two limitations: it is not commodity specific, and ignores household composition.

To incorporate the effects of the changing age and sex ratio of the population, N will be measured as a function of both household size and the changing age-sex structure of the population. The household size of the representative household is assumed to be equal to the average household size of the population. Analogously, the age and sex composition of the representative household is assumed to be equal to the average age and sex composition of the population. Adult equivalent scale research has shown that household members in different age and sex categories do not influence a households expenditures on food uniformly. The expenditures of an additional member from a given age-sex category can be measured in terms of adult male equivalents. The demographic variable, N_t, will be defined as the adult equivalent household size:

$$N_t = \text{Adult Equivalent Household Size} = \frac{\text{Adult Equivalent Population}_t}{\#\text{ of households}_t}.$$

The adult equivalent household size is obtained by dividing the adult equivalent population by the number of households in the population. The adult equivalent population for a given year is obtained by multiplying a particular adult equivalent scale by the number of persons in the corresponding age-sex cell and summing across cells.

It would be optimal if an adult equivalent scale was available for each commodity in the demand system. Unfortunately, adult equivalent scales have not be developed to correspond to the exact commodity bundles used in this analysis. Adult equivalent scales for total food expenditures, though, have been developed.

Much of how the demographic parameter affects the demand system is dependent upon the particular adult equivalent scale used to calculate the adult equivalent household size. Originally, adult equivalent scales were formulated using constant age-sex categories (Price; Prais and Houthakker). More recently adult equivalent scales have been modeled as a continuous function of age and sex (Buse and Salathe; Blokland; Tedford et al.). Tedford, Capps, and Havlicek (TCH) use the 1977-78 Nationwide Food Consumption survey to obtain adult equivalent scales for total at home food consumption. In that study, the same data is used to generate adult equivalent scales for the methods outlined by Buse and Salathe and by Blokland. The major difference between the TCH study and the other two is that the developmental and transitional phases of the human life cycle are used by TCH to derive the adult equivalent scales. TCH note that their empirical results are similar to those of the Buse and Salathe, while the Blokland model is too restrictive to explain consumer behavior over the life cycle. The TCH adult equivalent scale model was used to develop the adult equivalent population and adult equivalent household size in this study.

Because a single adult equivalent scale formulation was used to derive the adult equivalent population, it is implicitly assumed that the consumption behavior of household members within different age-sex classifications do not change over time. For example, a three year old in 1950 will be weighted the same in terms of adult male equivalents as a three year old in 1984. The assumption, however, is far less stringent than assuming that the representative consumer in 1950 is identical to the representative consumer in 1984. The graph also illustrates the importance of recognizing how changing the age and composition of the household members over time affects the adult equivalent scales relative to the more simplistic assumption that each person should carry the same weight of 1.0 adult equivalent.

To illustrate the difference between the adult equivalent population and total population, the ratio of the adult equivalent population to total population is graphed over the years 1950 to 1984 (Figure 1). The graph illustrates that between 1950 and 1962 the ratio was declining due to an increase in the proportion of the population in age-sex cells with smaller adult male equivalents. From 1962 to 1984 the proportion of the population in age-sex cells with large adult male equivalents was increasing.

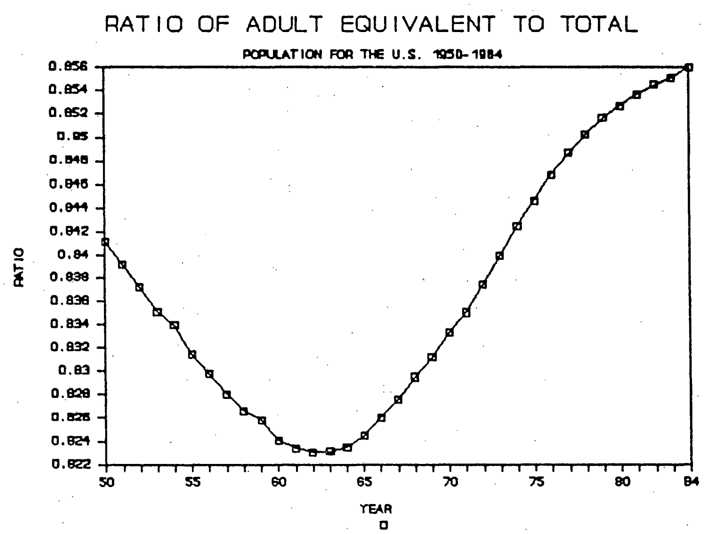

Figure 1: Ratio of the Adult Equivalent Population to the Total Population for the U.S. 1950-1984.

To illustrate the affect that the changing age-sex structure of the population has on household food expenditures, the total adult equivalent household food expenditures and per-capita food expenditures have been plotted in Figure 2. Since household size has been declining gradually since 1950, if the changing age-sex effects were insignificant, the two series would converge over time. But, because of the growth in the proportion of adult male equivalents in the population, the series have diverged since 1962.

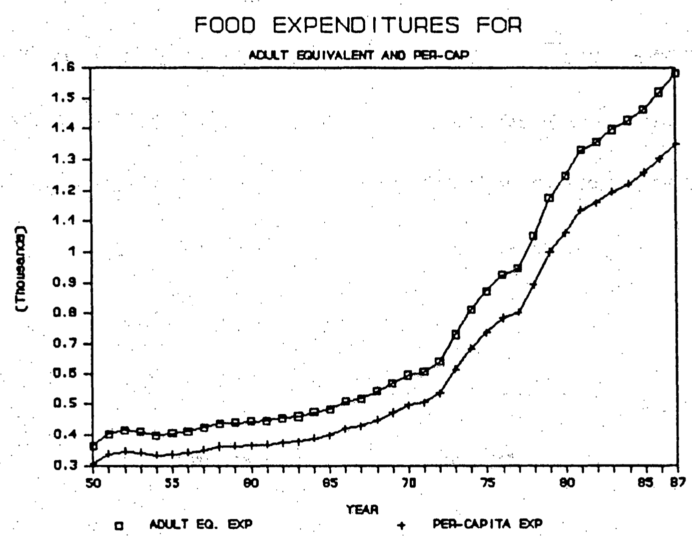

Figure 2: Adult Equivalent Household Food Expenditures and Per-capita Food Expenditures for the U.S. 1950-84.

CHOICE SET

Two choice sets of both eleven and four food commodities were used to estimate the per-capita and adult equivalent household AIDS model. The commodities in the eleven commodity choice set were 1) beef and veal 2) pork products 3) fish 4) poultry products 5) eggs 6) dairy products 7) fruits and vegetables 8) cereals and bakery products 9) sugars and sweeteners 10) fats and oils and 11) beverages. This paper concentrates on the smaller four commodity set of three meat commodities, beef, pork, and poultry, and an aggregate of the remaining eight commodities in the eleven commodity system. The results from using the eleven commodity set to estimate the model are available upon request. Limiting the demand system to four food commodities allows for closer inspection of the consumption relationships between the commodities in the system.

This system differs from some other demand system analysis of meat commodities because of the inclusion of a non-meat food group (Chalfant and Alston; Moschini and Mielke; Hayes, Wahl, and Williams). When this latter category is excluded, it is assumed that the meat commodities constitute a weakly separable group from other food commodities. Therefore, prices of the commodities excluded from the conditional system, such as dairy products, are assumed to have no direct influence on the quantity consumed of the meat commodities.

Annual time series data for the U.S. (1950-84) were used to estimate a per-capita and adult equivalent household AIDS model for four food groups. The data for the per-capita specification consisted of price indexes and per-capita food expenditures for each of the four commodities. The data for the adult equivalent specification consisted of data on the price indexes and household food expenditures of the four commodity groups plus a measure of the adult equivalent population.

The price indexes for beef, pork, and poultry were found in various issues of Food Consumption and Expenditures (FCPE). The price index for the non-meat group was a weighted average of the price indexes for the eight non-meat categories. These price indexes were also found in various issues of the FCPE.

The per-capita expenditures for beef, pork, and poultry were derived from information on per-capita consumption and price information using the method described in Blanciforti, Green, and King. The per-capita expenditures for the non-meat group was the summation of the per-capita expenditures for the eight non-meat commodities. Expenditure series for the three commodity groups, fruits and vegetables, cereals and bakery products and dairy products, were found in various issues of the FCPE. The expenditure series for the remaining five commodities were calculated following the method described in Blanciforti, Green, and King.

Household expenditures for each of the four commodities were derived by multiplying the per-capita expenditures by the U.S. average household size. The adult equivalent household model includes a demographic variable which is the ratio of the total population to the adult equivalent population multiplied by average household size. The population data for computing the adult equivalent population and the total population were found in various issues of the U.S. Bureau of Census Current Population Reports by age and sex categories.

RESULTS

The adult equivalent household AIDS model (7) was estimated unrestricted and with homogeneity and symmetry imposed on the system of equations. The unrestricted coefficients, which were estimated using ordinary least squares (OLS), are reported with their corresponding R^2 and Durbin-Watson statistics in Table I.

The homogeneity restriction was tested for each equation in the system by evaluating the F-ratios obtained by comparing the sum of squared errors from each of the unconstrained and homogenous equations. Each of the equations in the adult equivalent household model accepted the homogeneity restriction at the five percent significance level. The homogeneous parameter estimates and their corresponding Durbin-Watson statistics and F-ratios are reported in Table II.

The adult equivalent household system was tested for its acceptance of the Slutsky symmetry restrictions. Because it is necessary that these restrictions be tested as a system, the symmetry restricted coefficients were estimated using the Seemingly Unrelated Regression (SUR) technique. A system of n-1 equations was estimated for the model (Table III). The symmetry restrictions were tested using the Likelihood Ratio test. The test

TABLE 1 UNRESTRICTED PARAMETER ESTIMATES FOR THE ADULT EQUIVALENT HOUSEHOLD AIDS MODEL

Commodity	Price Coefficients				Expenditures	Demographic Coefficient	Intercept	Average Budget Share	R^2	Durbin Watson
	Beef	Pork	Poultry	Non-meat						
Beef	.0577	.0651	-.0105	-.1270	.2762	-.4540	-.0481	.1653	.90	1.62
	(4.90)[a]	(4.62)	(-.683)	(-4.04)	(3.82)	(-2.60)	(-.13)[a]			
Pork	.0229	.0147	.0262	-.0748	-.0007	-.1322	.2764	.0983	.87	2.28
	(5.01)	(2.69)	(4.39)	(-6.41)	(-.03)	(-1.95)	(1.91)			
Poultry	.0079	.0064	.0127	-.0276	.0008	-.0630	.1031	.0443	.74	1.53
	(3.04)	(2.06)	(3.75)	(-3.97)	(.06)	(-1.63)	(1.25)			
Non-Meat	-.0885	-.0861	-.0284	.2293	-.2764	.6492	.6686	.6922	.86	1.87
	(-6.61)	(-5.39)	(-1.63)	(6.43)	(-3.37)	(3.27)	(1.58)			

[a]T statistics for estimated coefficients are shown in parenthesis.

TABLE 2 HOMOGENEOUS PARAMETER ESTIMATES FOR THE ADULT EQUIVALENT HOUSEHOLD AIDS MODEL

Commodity	Price Coefficients: Beef	Price Coefficients: Pork	Price Coefficients: Poultry	Price Coefficients: Non-meat	Expenditures	Demographic Coefficient	Intercept	Average Budget Share	Durbin Watson	F
Beef	.0577 (4.96)[a]	.0640 (4.66)	-.0077 (-.54)	-.1140 (-6.13)	.2941 (4.70)	-.3797 (-3.91)	-.2349 (-2.86)	.1653	1.65	.26
Pork	.0229 (5.01)	.0138 (2.57)	.0283 (5.09)	-.0650 (-8.90)	.1028 (.52)	-.1761 (-2.00)	.1355 (4.20)	.0983	2.15	1.00
Poultry	.0079 (3.09)	.0064 (2.10)	.0128 (4.12)	-.0271 (-6.63)	.0015 (.11)	-.0600 (-2.83)	.0963 (5.32)	.1443	1.54	.01
Non-Meat	-.0885 (-6.66)	-.0842 (-5.36)	-.0335 (-2.07)	.2062 (9.70)	-.3084 (-4.32)	.5161 (4.65)	1.0031 (10.67)	.6922	1.84	.66

[a]T statistics for estimated coefficients are shown in parenthesis.

TABLE 3 SYMMETRIC PARAMETER ESTIMATES FOR THE ADULT EQUIVALENT HOUSEHOLD AIDS MODEL

Commodity	Price Coefficients: Beef	Pork	Poultry	Non-meat	Expenditures	Demographic Coefficient	Intercept	Average Budget Share
Beef	.0618	.0270	.0074	-.0963	.3654	-.4772	-.3296	.1653
	(5.36)[a]	(6.33)	(2.94)	(-7.50)	(10.82)	(-14.01)	(-5.25)	
Pork	.0270	.0176	.0125	-.0571	-.0457	.0262	.1915	.0983
	(6.33)	(3.56)	(4.81)	(-8.58)	(-2.83)	(1.27)	(7.16)	
Poultry	.0074	.0125	.0099	-.0297	-.0120	-.0411	.1136	.0443
	(2.94)	(4.81)	(3.28)	(-7.49)	(-.90)	(-1.98)	(6.47)	
Non-Meat	-.0963	-.0571	-.0298	.1831	-.3078	.4921	1.0245	.6922
	(-7.50)	(-8.58)	(-7.48)	(10.84)	(-7.74)	(11.43)	(14.16)	

[a]T statistics for estimated coefficients are shown in parenthesis.

compared the errors derived from the symmetry imposed system of n-1 equations and a system of the same n-1 equations with homogeneity imposed on each equation. Slutsky symmetry was accepted by the system at the five percent significance level.

The per-capita AIDS model was estimated unrestricted and with homogeneity imposed on each of the equations in the system. The unrestricted estimates are presented in Table IV. As with the adult equivalent household model, the homogeneity restriction was tested for each equation in the system using and F-test. With the exception of the beef equation, each equation in the system rejected the homogeneity restriction. The F-values computed from the unrestricted and homogeneous error sum of squares are reported in Table IV. In addition, the Durbin-Watson statistics from the homogenous results are reported in Table IV.

The testing of the Slutsky symmetry restrictions involves comparing the error from the symmetry imposed system of n-1 equations with the errors from the homogeneity constrained system of (n-1) equations. When homogeneity is rejected by the system, it is not appropriate to test the system for acceptance of the Slutsky symmetry restriction. The homogeneity restriction was tested for the system of n-1 equations by computing an F value from the sum of squared errors for the system of n-1 equations unconstrained and with homogeneity imposed. The coefficients were estimated using the SUR technique. Homogeneity was rejected for the system of n-1 equations at the five percent significance level. Laitinen has suggested a correction for the F-statistic to account for over rejection of the homogeneity restriction. Even when this adjustment was made, the homogeneity restriction was rejected.

In Deaton and Muellbauer's original study of British household expenditures, several of the equations in the system failed to accept the homogeneity restriction. And, when the restriction was imposed on the model, serial correlation was induced in those equations

TABLE 4 UNRESTRICTED PARAMETER ESTIMATES FOR THE PER-CAPITA AIDS MODEL

	Price Coefficients									Homogenous Model	
Commodity	Beef	Pork	Poultry	Non-meat	Expen-ditures	Intercept	Average Budget Share	R^2	DW	DW[a]	F[b]
Beef	.0537	.0591	-.0144	-.0964	.2898	-.2539	.1653	.90	1.63	1.57	.17
	(4.76)[c]	(4.34)	(-1.13)	(-6.27)	(4.89)	(-2.57)					
Pork	.0224	.0123	.0294	-.0554	.0267	.0167	.0983	.86	2.04	.89	17.14*
	(4.76)	(2.16)	(5.52)	(-8.63)	(1.08)	(.41)					
Poultry	.0078	.0061	.0129	-.0184	.0061	-.0054	.0443	.71	1.26	.85	48.26*
	(2.92)	(1.88)	(4.25)	(-5.03)	(.43)	(-.23)					
Non-Meat	-.0840	-.0775	-.0279	.1701	-.3226	1.2427	.6922	.86	1.76	1.02	10.63*
	(-6.40)	(-4.89)	(-1.88)	(9.51)	(-4.68)	(10.79)					

[a]Durbin Watson statistics in this column are from homogeneity restricted models.

[b]Asterisk denotes rejection of the homogeniety restriction. F test was calculated using sum of squared errors from unrestricted and homogeneity restricted equations.

[c]T statistics for estimated coefficients are shown in parenthesis.

rejecting the restriction. The authors noted that this problem may be due to their assumption that the demographic deflator present in the original AIDS model was constant or their omission of relevant variables explaining inflexible expenditures. Blanciforti, Green, and King have addressed this latter issue by their development of the dynamic AIDS model. In their results from a food demand system, when homogeneity was imposed on the system, autocorrelation was not induced in the model. However, homogeneity was still rejected by their dynamic system of equations.

The most striking result from this analysis was the adult equivalent household models acceptance of the underlying theoretical restrictions of homogeneity and Slutsky symmetry. In addition, modelling the demographic deflator in the AIDS model provides information on the affects of changing demographics on food consumption.

The demographic coefficients for the beef and poultry commodity groups in the symmetric adult equivalent household model were negative and significant. This implies that an increase in the adult equivalent household size, caused by either an increase in household size or an increase in the proportion of adult male equivalents in the population, would have a negative effect on the budget shares of beef or poultry. On possible explanation for this is an income effect. As household size increases, the total food expenditures allotted per-person would decline inducing the household to decrease its consumption of food commodities which are not necessities.

The demographic coefficients in the pork and non-meat equation in the symmetric model were positive. However, only the demographic coefficient in the non-meat category was significant at the five percent level. The positive demographic coefficient indicates that as the adult equivalent household size increases the proportion of total food expenditures allocated to non-meat increases. As with the demographic coefficient in the beef equation, this could be explained by an income effect. Another possible explanation could be that as the population ages, the proportion of adult equivalent persons in the population increases. Cross sectional studies have shown that households with larger proportions of older persons allocate a smaller proportion of their food budget to the meat commodities, and therefore a larger proportion to non-meats (Cox, Buse, and Alvarez).

The expenditure coefficient, β_i, measures the effect of a real increase in total food expenditures on the budget share of the i^{th} food commodity. In the symmetric adult equivalent household model, the expenditure coefficient for beef was positive and significant. The expenditure coefficients for pork and the non-meat group were negative and significant.

The own price coefficients, g_{ii}, measure the effect on the i^{th} budget share of an increase in the price of the i^{th} commodity, with all else remaining constant. In the symmetric adult equivalent model, all of the own price coefficients were positive. In the symmetric adult equivalent household model all of the cross price coefficients, g_{ij}, in the meat subgroup were positive and all of the cross price coefficients for non-meats were negative. All of the price coefficients were significant.

The expenditure and Hicksian elasticities for the unrestricted per-capita model and the symmetric adult equivalent household model are presented in Table V. The Hicksian elasticity estimates for the symmetric adult equivalent household model indicate that all of the goods in the system are net substitutes. Each of the income compensated own price elasticities are negative. Due to a significant income effect, the unreported Marshallian cross price elasticities for pork and poultry in the beef equation had a negative sign, indicating that the goods are substitutes. The Hicksian elasticities calculated from the unrestricted per-capita coefficients were similar in magnitude to the Hicksian elasticities calculated from the symmetric adult equivalent household parameter estimates. However, two of the cross price elasticities within the meat subgroup have a negative sign indicating net complementarity.

TABLE V

EXPENDITURE AND HICKSIAN PRICE ELASTICITY ESTIMATES CALCULATED FROM THE SYMMETRIC ADULT EQUIVALENT HOUSEHOLD AIDS COEFFICIENTS

	Beef	Pork	Poultry	Non-meat	Expenditures
1) Beef	-.46	.26	.09	.11	3.21
2) Pork	.44	-.72	.17	.11	.53
3) Poultry	.33	.38	-.73	.02	.73
4) Non-meat	.03	.02	.00	-.04	.56

EXPENDITURE AND HICKSIAN PRICE ELASTICITY ESTIMATES CALCULATED FROM THE UNRESTRICTED PER-CAPITA AIDS COEFFICIENTS

	Beef	Pork	Poultry	Non-meat	Expenditures
1) Beef	-.51	.46	-.04	.11	2.75
2) Pork	.39	-.78	.34	.13	1.27
3) Poultry	.34	.24	-.66	.28	1.14
4) Non-meat	.04	-.01	.00	-.06	.53

The formulae for the Hicksian own and cross price elasticities are:

$$\delta_{ii} = -1 + g_{ii}/w_i + w_i$$

$$\delta_{ij} = g_{ij}/w_i + w_j$$

The formula for the expenditure elasticity is:

$$n_i = 1 + \beta_i/w_i.$$

CONCLUSION

Demand systems analyzed at the aggregate level using time series data have generally assumed that the changing demographic structure of the population is constant over time. This paper has outlined how information from cross sectional analysis of food consumption combined with population data can be incorporated into time series demand analysis. An AIDS model incorporating variation in age and sex composition of the population as well as household size was developed. In both an eleven and four commodity food demand system, autocorrelation was not induced when homogeneity was statistically imposed on the system. In addition, when the homogeneity restriction was tested, both model accepted the restriction overall.

Although this paper used the Almost Ideal Demand System as its theoretical framework, other demand system specifications could be used. Admittedly, the choice of adult equivalent scales and demographic factors will affect the results. Further research needs to be done in this area. The results from this study indicate that data based demographic information should be incorporated into demand systems.

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