Demand for Healthy Food in the United States

Xudong Feng and Wen S. Chern*

* Xudong Feng and Wen S. Chern are, respectively, Research Associate and Professor, Department of Agricultural, Environmental, and Development Economics, The Ohio State University, Columbus, OH 43210-1066.

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Abstract

This study investigates the demand for selected healthy food groups in the United States. The original linear approximate almost ideal demand system (LA/AIDS) is modified by the use of a Laspeyres index and a normalization in order to compute demand elasticities identically to the AIDS model. The results of this study suggest that poultry is the most price elastic while cereals are the least price elastic. Fresh fruits and fresh vegetables are more price elastic than processed fruits and processed vegetables. Increasing income would induce the increases in the consumption of fresh vegetables and fruits more than that of cereals and bakery products, while increasing health risk concerns would induce the decreases in the consumption of bakery products and poultry but the increases in the consumption of fresh vegetables and cereals. The demographic variables exhibit certain effects on the demand for some healthy food groups and seasonal fluctuations statistically exist in the consumption of all food groups under study.

Key Words: AIDS model, elasticity, healthy food, household demand, United States.

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The empirical estimation of healthy food demand functions has long been of interest not only to food producers and economic analysts but also to dietitians and nutritionists. Scientific evidences increasingly suggest that healthy diets—which mean abundant in grains, vegetables, and fruits, and low in total fat, saturated fat, and cholesterol—combined with moderate and regular physical activity can reduce the risk for food related diseases such as coronary heart disease, cancer, stroke, and diabetes (Kantor, 1999). These diseases account for nearly two-thirds of all deaths in the United States each year (Frazao, 1999). Although there appears to be changes towards a healthier diet, a considerable gap still exists between actual nutrient intakes of the consumer and public health recommendations (Huang, 1999). Further research is needed to improve our understanding of how consumer behavior affects food choices besides how diet affects health.

Few studies have incorporated both nutrition related and demographic factors into food demand systems (Nayga *et al*., 1999). The objective of this study is to investigate the effects of not only economic factors such as food prices and consumer income but also various demographic and health related variables as well as seasonal dummy variables on the consumption of seven selected healthy food groups in the United States. Cereals and bakery products are included in our study because they are the basic and subsistence foods in the *Food Guide Pyramid* (USDA, 1992). Fruits and vegetables in both fresh and processed forms are under our study since they are the most important healthy food to keep cancer away. Poultry is usually not included in the healthy food category. However, comparing with red meats such as pork, beef, and mutton, poultry is healthier since it contains lower cholesterol. Moreover, there have been increasing consumption trends for chicken and turkey, and decreasing consumption trends for other meats. These trends are believed to relate to medical and dietary concerns of a perceived linkage between heart disease and cholesterol levels (Huang, 1993). Thus, poultry as a favorite protein food is also chosen in this study. Since it maybe difficult to justify a weak separability of these healthy foods from other foods, an aggregate group of all other foods is included in the model. The monthly data series created from consumer expenditure surveys from 1981 to 1995 are used for the analysis.

Ever since Richard Stone (1954) proposed the Linear Expenditure System (LES) as the first complete demand system, there has been a continuing search for new systems. Among proposed models afterwards, the Rotterdam model that was first proposed by Theil (1965) has most frequently been used to test the homogeneity and symmetry restrictions of demand theory in the late 1960s. The Transcendental Logarithmic (Translog) system of Christensen *et al*. (1975) has been extensively estimated in the late 1970s. But one of the most widely used flexible demand specifications in recent decades is the almost ideal demand system (AIDS) developed by Deaton and Muellbauer (1980).

While the AIDS possesses many desirable properties, it may be difficult to estimate. Therefore, the linear approximate almost ideal demand system (LA/AIDS) using the Stone share weighted price index has been widely employed to simplify the estimation process. However, since LA/AIDS is not itself derived from a well-specified representation of preferences and it can violate the symmetry restrictions of consumer demand theory, several problems have been raised (Green and Alston, 1990; Alston *et al*., 1994; Hahn, 1994). Buse (1994) showed that the parameter estimates of LA/AIDS by Seemingly Unrelated Regressions (SUR) are inconsistent. Moreover, the units of measurement will strongly affect the performance of the estimated demand system (Chung, 1993; Moschini, 1995). Fortunately, Asche and Wessells (1997) have shown that LA/AIDS model is equivalent to the AIDS model if the systems are evaluated at the point of price normalization to unity.

To gain additional benefit from the above studies, this paper will present the estimation of a modified linear approximate almost ideal demand system (Modified LA/AIDS) for seven healthy food groups with both homogeneity and symmetry constraints imposed. The modified LA/AIDS incorporates two features. First, the Laspeyres index is used to replace the Stone index in order to improve the quality of approximation to the true nonlinear AIDS and to remove the problems of inconsistency and simultaneity (Moschini, 1995). Second, the prices in the system are normalized to one at the point where elasticities are reported because the expressions for price and expenditure elasticities are identical between AIDS and LA/AIDS at the data point where prices are unity (Asche and Wessells, 1997).

Demographic variables have traditionally played a major role in the analysis of household budget data. This paper will investigate whether family size, age of household head, number of wage earners, and annual value of food stamps received by household affect the household consumption patterns on the selected healthy foods. Moreover, since we are studying the demand for healthy foods, the impacts of changing health risk concerns on their demand will also be investigated. Scientific evidence increasingly suggests that diets high in total fat, saturated fat, and cholesterol are closely associated with an increased risk for coronary heart diseases (Frazao, 1999). There is no doubt that an increasing amount of health information about the adverse effects of saturated fat and dietary cholesterol has influenced food consumption patterns. The fat and cholesterol information index from MEDLINE database (FCIM) developed by Chern and Zuo (1995) based on an improved methodology from Brown and Schrader (1990) will be applied here in the same way as demographic variables. Specifically, this health information index, FCIM, is a cubic weighting function of published medical journal articles, formulated on the assumption that an article published in a specific time period has both carryover and decay effects.

The paper is organized as follows. The next section of this paper develops the modified LA/AIDS for healthy food demand with demographic, health information, and seasonal dummy variables incorporated and then derives the expenditure elasticity and the uncompensated and compensated price elasticities from the modified LA/AIDS. This is followed by the description of data and the method used to estimate the model. Next, we describe the homogeneity and symmetry tests, and then present the results estimating the constrained modified LA/AIDS. Moreover, the impacts of demographic and health information variables on consumption patterns and the seasonal effects are also examined. The final section summarizes major findings and conclusions.

A Demand Model for Healthy Food

Following Deaton and Muellbauer (1980), the AIDS budget share equations can be written as:

$$w_{it} = \alpha_i + \sum_j \gamma_{ij} \ln(p_{jt}) + \beta_i \ln(x_t/P_t) + u_{it}, \qquad i = 1, \ldots, n;\ t = 1, \ldots, T. \qquad (1)$$

where, in time t, w_{it} is the budget share of good i, p_{jt} is the price of good j, x_t is total expenditure of the goods under consideration, u_{it}'s are random disturbances with zero mean and no serial correlation, and P_t is a translog price index defined as:

$$\ln(P_t) = \alpha_0 + \sum_k \alpha_k \ln(p_{kt}) + (1/2) \sum_j \sum_k \gamma_{jk} \ln(p_{jt}) \ln(p_{kt}). \qquad (2)$$

The adding-up restriction requires that $\sum_i w_i = 1$, which is satisfied in the AIDS provided:

$$\sum_i \alpha_i = 1,\ \sum_i \gamma_{ij} = 0, \text{ and } \sum_i \beta_i = 0, \qquad j = 1, \ldots, n. \qquad (3)$$

The homogeneity is satisfied for the AIDS if and only if, for all *i*:

$$\sum_j \gamma_{ij} = 0, \qquad i = 1, \ldots, n. \qquad (4)$$

The symmetry is reflected by:

$$\gamma_{ij} = \gamma_{ji}, \qquad i, j = 1, \ldots, n. \qquad (5)$$

It is obvious that Equations (3)–(5) are implied by utility maximization. However, unrestricted estimation of Equation (1) will only automatically satisfy the adding up restrictions so that the AIDS offers the opportunity of testing homogeneity and symmetry by imposing Equations (4) and (5).

Using the price index in Equation (2) often raises empirical difficulties due to nonlinearity in parameters and particularly in estimating α_0, so it is common to replace the translog price index P with the Stone price index P^*:

$$\ln(P^*_t) = \sum_i w_{it} \ln(p_{it}). \qquad (6)$$

The Stone price index is an approximation proportional to the translog index, that is,

$$P_t = \xi_t P^*_t, \qquad (7)$$

where $E(\ln(\xi_t)) = \alpha_0$. Substitution of Equation (6) rather than Equation (2) into Equation (1) yields the LA/AIDS model:

$$w_{it} = \alpha^*_i + \sum_j \gamma_{ij} \ln(p_{jt}) + \beta_i \ln(x_t/P^*_t) + u^*_{it}, \qquad i = 1, \ldots, n, \qquad (8)$$

where $\alpha^*_i = \alpha_i - \beta_i \alpha_0$ and $u^*_{it} = u_{it} - \beta_i (\ln(\xi_t) - E(\ln(\xi_t)))$.

Because prices are never perfectly collinear, which is the condition for Equation (7), the Stone index introduces a measurement error. To overcome this problem, Laspeyres index can be used to replace the Stone index (Moschini, 1995) and the prices in the system should be normalized to one at the point where elasticities are reported. At the data point where prices are unity, the expressions for price and expenditure elasticities are identical between AIDS and LA/AIDS as showed by Asche and Wessells (1997).

The loglinear analogue of the Laspeyres price index is:

$$\ln(P^L_t) = \sum_i w^0_i \ln(p_{it} / p^0_i), \tag{9}$$

where the superscript 0 denotes the base period and in that case, the sample means of our data series. Note that if the prices are normalized to one ($p^0_i = 1$) before the index is computed, the Laspeyres price index reduces to the geometrically weighted average of prices:

$$\ln(P^G_t) = \sum_i w^0_i \ln(p_{it}). \tag{10}$$

Substitution of Equation (10) into Equation (1) yields the modified LA/AIDS model:

$$w_{it} = \alpha^{**}_i + \sum_j \gamma_{ij} \ln(p_{jt}) + \beta_i (\ln(x_t) - \sum_j w^0_j \ln(p_{jt})) + u^{**}_{it}, \tag{11}$$

where $\alpha^{**}_i = \alpha_i - \beta_i (\alpha_0 - \sum_j w^0_j \ln(p^0_j))$ and it reduces to α^*_i when $p^0_j = 1$. It is obvious that the equations are linear in parameters. Moreover, the problem of simultaneity is removed because w^0_j's are fixed from the given data, so the above model is ideal for our empirical investigation.

Demographic and health information variables as well as seasonal dummy variables are incorporated into the modified LA/AIDS using the demographic translating procedure proposed by Pollak and Wales (1978). Linear translating replaces the demand system in Equation (11) by the modified system:

$$w_{it} = \alpha^{***}_{i} + \sum_k \delta_{ik}\, \eta_{kt} + \sum_j \gamma_{ij} \ln(p_{jt}) + \beta_i\, (\ln(x_t) - \sum_j w^0_j \ln(p_{jt})) + u^{***}_{it}, \tag{12}$$

where $\alpha^{***}_{i} = \alpha^{**}_{i} - \sum_k \delta_{ik}\, \eta_{kt}$, η_{kt} is kth demographic, health information, or seasonal dummy variable at time t, and δ_{ik} is the associated coefficient in the ith budget share equation.

The adding-up restriction requires that:

$$\sum_i\alpha^{***}_{i} = 1, \text{ and } \sum_i\delta_{ik} = 0, \qquad k = 1, \ldots, m,$$

where m is the number of demographic, health information, and seasonal dummy variables in the system.

Elasticities of the Modified LA/AIDS

Taking a derivative of Equation (12) with respect to ln(x) one can obtain the total expenditure elasticities e_i as:

$$\begin{aligned} e_i &= 1 + (1/w_i)(\partial w_i / \partial \ln(x)) \\ &= 1 + (\beta_i / w_i). \end{aligned} \tag{13}$$

This expression is the same as that for the AIDS model.

Taking derivative of Equation (12) with respect to $\ln(p_j)$ yields uncompensated own ($j = i$) and cross ($j \neq i$) price elasticities e_{ij}:

$$\begin{aligned} e_{ij} &= -\,\delta_{ij} + (1/w_i)\,(\partial w_i / \partial \ln(p_j)) \\ &= -\,\delta_{ij} + (\gamma_{ij}/w_i) - (\beta_i/w_i)\, w^0_j, \qquad \forall\, i, j = 1, \ldots, n, \end{aligned} \tag{14}$$

where δ_{ij} is the Kronecker delta that is unity if $i = j$ and zero otherwise. This expression is identical to that of AIDS at the point of normalization and α_0 is set equal to the logarithm of expenditure in the base period as shown below.

At the point of normalization, the AIDS model in Equation (1) reduces to:

$$w^0_i = \alpha_i + \beta_i \ln(x^0) - \beta_i \alpha_0 = \alpha_i, \qquad \text{if } \alpha_0 = \ln(x^0).$$

The uncompensated elasticity for the AIDS model at the point of normalization:

$$\begin{aligned} e_{ij\,(AIDS)} &= -\delta_{ij} + (\gamma_{ij}/w_i) - (\beta_i/w_i)(\alpha_j + \textstyle\sum_k \gamma_{kj} \ln(p_k)) \\ &= -\delta_{ij} + (\gamma_{ij}/w_i) - (\beta_i/w_i)(w^0_j + \textstyle\sum_k \gamma_{kj} \ln(p^0_k)) \\ &= -\delta_{ij} + (\gamma_{ij}/w_i) - (\beta_i/w_i)\, w^0_j, \end{aligned}$$

where the second step uses $\alpha_j = w^0_j$ and last step comes from $p^0_k = 1$.

Now, we can derive the Hicksian compensated price elasticities for the modified LA/AIDS since these elasticities provide a means of assessing the structure of economic interdependence among consumer demand for healthy foods. In the modified LA/AIDS, the compensated price elasticities s^*_{ij} at the point of normalization can be computed from parameters γ_{ij} directly as shown below:

$$\begin{aligned} s^*_{ij} &= e_{ij} + e_i w_j \qquad\qquad (15) \\ &= -\delta_{ij} + (\gamma_{ij}/w^0_i) + w^0_j, \qquad \forall\, i, j = 1, \ldots, n. \end{aligned}$$

This expression is identical to that of the AIDS model where $p_i = p^0_i = 1$ and $w_i = w^0_i$, as the expressions for the uncompensated elasticities and the expenditure elasticities are equal in both models at the point of normalization.

The Slutsky substitution matrix can be easily derived for checking symmetry and negativity. The Slutsky substitution matrix s_{ij} can be expressed as:

$$s_{ij} = s^*_{ij}\, q_i / p_j = (-\,\delta_{ij} + (\gamma_{ij}/w^0_i) + w^0_j)\,(q_i / p_j), \qquad \forall\, i, j = 1, \ldots, n. \tag{16}$$

Symmetry condition of $s_{ij} = s_{ji}$ can be evaluated by Equation (5) at the point of normalization as shown in the following:

$$\begin{aligned} s_{ij} = s_{ji} &\Leftrightarrow (-\,\delta_{ij} + (\gamma_{ij}/w^0_i) + w^0_j)\,(p^0_i\, q^0_i) / x = (-\,\delta_{ji} + (\gamma_{ji}/w^0_j) + w^0_i)\,(p^0_j\, q^0_j) / x \\ &\Leftrightarrow (-\,\delta_{ij}\, w^0_i + \gamma_{ij} + w^0_i\, w^0_j) = (-\,\delta_{ji}\, w^0_j + \gamma_{ji} + w^0_i\, w^0_j) \\ &\Leftrightarrow \gamma_{ij} = \gamma_{ji}, \end{aligned}$$

where the last step comes from $\delta_{ij}\, w^0_i = \delta_{ji}\, w^0_j$. Since γ_{ij}'s are estimated first, it is most common to use Equation (5) for checking the symmetry condition.

One approach to examine the negativity condition is based on the parameters themselves. Fortunately, the condition for the Slutsky matrix to be negative semidefinite is equivalent to that for the following matrix C to be negative semidefinite for the modified LA/AIDS at the point of normalization:

$$c_{ij} = s_{ij}\, p_i\, p_j / x = \gamma_{ij} - w^0_i\, \delta_{ij} + w^0_i\, w^0_j, \qquad \forall\, i, j = 1, \ldots, n. \tag{17}$$

Data and Estimation Methods

The modified LA/AIDS model in Equation (12) is used in empirical investigation. The monthly data series of the United States were obtained for a 15-year span, 1981 to 1995 (T = 180). The database includes weekly expenditure by month and monthly consumer price index (CPI) of seven healthy food groups and one other foods group (n = 8). Seven healthy food groups are fresh fruits (i = 1), fresh vegetables (i = 2), processed fruits (i = 3), processed vegetables (i = 4), cereals and cereals products (i = 5), bakery products (i = 6), and poultry (i = 7). Subtracting the sum of the expenditures of above seven healthy food groups from per-household expenditures on food yields expenditure on other foods group (i = 8). The CPI for food is used for this composite group. Average family size (denoted as η_1), average age of household head in years (η_2), average number of wage earners (η_3), average annual value of food stamps received by household (η_4), the fat and cholesterol information variable (FCIM) (η_5), and two seasonal dummy variables are included in the general category of demographic variables. The data for expenditure and demographic variables were obtained directly from the household data from the Consumer Expenditure Surveys conducted by the Bureau of Labor Statistics (BLS) with the exception of FCIM that was provided by Chern and Zuo (1995). Two seasonal dummy variables represent Winter (η_6) and Summer (η_7) respectively in this study. Winter consists of November through February while Summer includes May through August. Before estimation, all prices in the system are normalized so that the prices are unity at the mean point where elasticities are evaluated.

It is obvious that the modified LA/AIDS equations without restrictions described in Equation (12) are linear in parameters and simultaneity problem free, so the seemingly unrelated regressions (SUR) estimator is consistent. This is an improvement since SUR is not consistent in estimating the original LA/AIDS as mentioned before. Moreover, where there are no cross-equation restrictions such as symmetry, the estimation can be conducted equation by equation by ordinary least squares (OLS) which, in this case and given normally distributed errors, is equivalent to the maximum likelihood estimation for the system as a whole. But the imposition of homogeneity and symmetry may generate positive serial correlation in the residuals, moreover, the variance-covariance matrix of residuals plays a part in the estimation since symmetry involves cross-equation restrictions, neither OLS nor SUR that are used to estimate the constrained LA/AIDS will be consistent. To circumvent this problem, the maximum likelihood estimators (MLE) or the iterative seemingly unrelated regression procedure (ITSUR) can be used. Since ITSUR and MLE generate the same results but ITSUR converges faster than MLE, ITSUR was chosen to estimate our constrained LA/AIDS model described by Equation (12). The other benefit of using ITSUR or MLE is that they are invariant to the normalization such that we will obtain the same parameter estimates no matter which equation is dropped in our system.

Empirical Results

Homogeneity and symmetry test

As mentioned before, the AIDS offers an opportunity to test homogeneity and symmetry by imposing Equations (4) and (5), so does the modified LA/AIDS. Table 1 provides the relevant test results for homogeneity and symmetry with the data under study. The subscripts of gamma represent relevant food groups: 1 for fresh fruits, 2 for fresh vegetables, 3 for processed fruits, 4 for processed vegetables, 5 for cereals and cereals products, 6 for bakery products, 7 for poultry, and 8 for the other foods group. Based on the estimates and variance-covariance matrix, each likelihood ratio test statistic is asymptotically distributed as χ^2 with one degree of freedom. The test results in the last column of Table 1 indicate that homogeneity can be satisfied at the 5% significance level but it is rejected for the group of fresh vegetables at the 10% significance level. The symmetry condition is not held for the whole data since nine out of twenty-eight tests of symmetry are rejected at 5% significance level. There are significant asymmetric relations between processed fruits and cereals, between processed fruits and bakery products, between cereals and bakery products, between cereals and the other foods group, and between poultry and the other foods group, and so on. The failure of symmetry induces the rejection of the combined test of homogeneity and symmetry. So the modified LA/AIDS by linear translating method to fit these data does not entirely satisfy the theoretical restrictions for at least symmetry.

Without imposing the theoretical restrictions of homogeneity and symmetry, the estimated Hicksian compensated own price elasticity of cereals group is positive. In order to ensure the theoretical consistency of the estimated parameters, both homogeneity and symmetry are imposed. In addition to narrowing the gap between demand theory and empirical application, the constrained estimation procedure provides greater statistical efficiency to demand parameter estimates.

Estimation

The parameters of the constrained LA/AIDS with demographic and seasonal variables are estimated by dropping one equation which is for the other foods group and applying the iterative seemingly unrelated regression procedure (ITSUR) in SAS (Statistical Analysis System). The regression results summarized in Table 2 show the values of the estimated coefficients and their absolute t-values. The last column in Table 2 represents the parameters of other foods group was obtained by using adding-up condition in Equation (3). The row of γ_{i8} can be generated by the homogeneity restriction in Equation (4), and the blank cells can be recovered by using symmetry condition in Equation (5).

The last two columns show the coefficient of determination R^2 values, and Durbin-Watson (DW) statistics for the constrained LA/AIDS. The model may seem poorly specified judging from R^2 values with the highest being only 0.84 for cereals group and the lowest being merely

0.32 for processed fruits. But R^2 can be extremely biased and inconsistent in time-series models (McGuirk and Driscoll, 1995). As we may see, there is no obvious relationship between R^2 and the DW statistic, which is different from the estimation results from the model without demographic variables, so we can not conclude that low R^2 values were induced by the autoregressive errors here.

Since we use the time-series data, the Durbin-Watson test may be used to examine the first-order autoregressive errors. Using the 5% significant level, the bound test concludes the presence of the autocorrelation only for poultry who has the lowest DW statistic of 1.53. The DW statistics are pretty high for other groups especially for fresh fruits group whose DW statistic reaches 2.09. So, there is no serious problem of first-order autoregressive errors in the system.

The adjusted R^2 and DW statistics between unconstrained and constrained modified LA/AIDS models with or without demographic and seasonal dummy variables are also compared. The results shows that the constrained model without demographic variables has the lowest adjusted R^2 and DW statistics, while the unconstrained model with demographic variables, especially, the seasonal dummy variables, has the highest adjusted R^2 and DW statistics. We may conclude that the imposition of homogeneity and symmetry generates positive serial correlation in the residuals and may be improved by demographic translating process.

At 10% level, the estimated parameters α_i's in Table 2 are all significantly different from zero but the estimated β_i's for fresh vegetables and processed fruits are insignificant. According to Equation (13), we can infer that the expenditure elasticities of fresh vegetables and processed fruits are not statistically different from unity. The β parameters of the AIDS determine whether goods are luxuries or necessities when the estimated model is a completed demand system where total expenditure can be viewed as disposal income. It is easy to show that with $\beta_i > 0$, the expenditure elasticity of good *i* is greater than unity, good *i*'s budget share w_i increases with total expenditure *x* so that good *i* can be viewed as a luxury in a complete demand system. Similarly, $\beta_i < 0$ implies that the good is a necessity. Here, the estimated β parameters except for fresh vegetables and processed fruits are all significant and negative, so we can conclude that the demand for fresh vegetables and processed fruits is more elastic with respect to total food expenditure than that for other groups. This will be verified when we analyze the total expenditure elasticities. The γ_{ij} parameters measure the change in the *i*th budget share following a proportional change in p_j with real total expenditure (x/P) being held constant. About half of the estimated γ_{ij} parameters in Table 2 are insignificant at 10% level. This indicates that their budget shares have almost no response to changes in own and cross prices.

The budget shares (expenditure weights) at sample means are shown first in Table 3. Processed vegetables and processed fruits groups have the lowest budget shares (1.8% and 2.4%, respectively) among the seven selected healthy food groups, while bakery products group has the highest budget share of 6.2%. The expenditure weights are all about 3 percent for other four healthy food groups, and that is, 3.3% for fresh fruits, 3.2% for fresh vegetables, 3.3% for cereals, and 2.9% for poultry. Other foods except these seven food groups account for 76.7% of total food expenditure. Using these results and Equations (13) and (14) as well as noting that prices were normalized to unity at the mean, the estimated expenditure elasticities and Marshallian uncompensated price elasticities can be computed at the sample means (Table 3).

All the estimated Marshallian own price elasticities are statistically significant and carry the expected negative signs. The estimated own price elasticities are close to unity for poultry (-0.883) and for fresh fruits (-0.820). In fact, the demand for these two groups has the largest response to changes in their relative prices than other healthy food groups, because the estimated own price elasticity is much smaller than unity for all others. The smallest and second smallest elasticities (in absolute values) are for cereals group (-0.090) and for processed fruits group (-0.267). We may conclude that the demands for cereals and processed fruits are inert to their price changes. The Marshallian cross price elasticities are generally much smaller than own price elasticities in magnitude as expected except that there exist large cross price elasticities between cereals and the other foods group (-0.960), and between processed fruits and cereals (-0.740).

The estimated total expenditure elasticities in Table 3 have the expected positive signs in all eight commodities. For fresh vegetables, processed fruits, and the other foods group, the estimated total expenditure elasticities (e_2 = 0.873, e_3 = 0.828, e_8 = 1.098) are much greater than others. This implies a fairly large response of demand for fresh vegetables and processed fruits to changes in total food expenditure. Actually, the demand for fresh vegetables and processed fruits are statistically unitary elastic with respect to total food expenditure as mentioned before. The estimated total expenditure elasticities of fresh fruits, processed vegetables, cereals, bakery products, and poultry are much less than unity, so these goods are fairly inelastic with respect to total food expenditure. As household income increases, the demand for fresh vegetables and processed fruits would increase more than that of cereals and bakery products. Among the seven selected healthy food groups, the cereals group not only has the smallest own price elasticity as mentioned above but also has the smallest expenditure elasticity (0.424).

Using Equation (15), the estimated Hicksian compensated price elasticities can be obtained directly from the estimated coefficients in Table 2. These elasticities are shown in Table 4. Compare to Marshallian own price elasticities, Hicksian own price elasticities are smaller in magnitude but have the same sign.

The estimated cross price elasticities between fresh fruits and fresh vegetables carry a negative sign. Thus, we may conclude that these two kinds of foods are complements as they may be purchased and consumed together. The same conclusion can be made for the pair of processed fruits and processed vegetables, the pair of fresh fruits and processed vegetables, and the pair of bakery products and poultry, and so on. While the estimated cross price elasticities between fresh vegetables and processed vegetables carry a positive sign, we may say that they are substitutes and the demand for one food group will increase if the price of the other increases. This is also true for fresh fruits and processed fruits as expected. Moreover, the same conclusion can be made for the pair of cereals and bakery products since they contain almost the same nutrition ratio and in the same level of *Food Guide Pyramid* (USDA, 1992).

The matrix C defined in Equation (17) was also computed to check negativity. Matrix C is symmetric since we imposed it before estimating the model. Although we did not impose the negativity condition since it cannot be ensured by any restrictions on the parameters alone, the necessary condition for negativity is satisfied since the diagonal elements of matrix C all carry a negative sign. Moreover, the sufficient condition for negativity is also satisfied because the signs of eight eigenvalues of matrix C are all negative.

Demographic, health concern and seasonal effects

The estimated demographic parameters δ_{ik}'s are shown in Table 5. A change in a demographic variable η_k causes a reallocation of expenditure among the consumption categories, and any increases in the consumption of some goods must be balanced by decreases in the consumption of others since total expenditure remains unchanged. So the demographic coefficient δ_{ik} represents the effect on budget share w_i of a change in the kth demographic variable (η_k) while holding the total expenditure x unchanged. Moreover, the sign of δ_{ik} is the same as the sign of the effect on expenditure on good i of a change in η_k in our model although it is not true generally for other demand systems by a linear demographic translating method.

Based on the absolute t-values in Table 5, the family size significantly affects the demand for fresh fruits, fresh vegetables, cereals, and poultry. Moreover, we can conclude that the bigger is the family size, the larger will be the budget share for these four groups since their respective demographic parameters carry a positive sign. Average age of household head affects the demand for processed fruits, processed vegetables, cereals, and bakery products in the same positive way, while the average number of wage earners affects the demand for fresh vegetables and poultry in the opposite way. That is, the more are the number of wage earners, the smaller the budget share for fresh vegetables and poultry since the respective demographic parameter carries a negative sign and is statistically significant. From the two significant and negative coefficients associated with annual value of food stamps received by household, we may infer that when annual value of food stamps received by the household increases, it will demand less for fresh and processed fruits.

Four out of seven parameters associated with the fat and cholesterol information index are significant at 10% level. The significant estimated parameters have a positive sign for fresh vegetables and cereals and a negative sign for bakery products and poultry. These signs are as expected since bakery products and poultry have a much higher content of fat and/or cholesterol comparing to other selected foods under study while fresh vegetables and cereals have been shown to offer health benefits in lowering the risk of heart disease and cancer. Therefore, an increase in availability of fat and cholesterol information will result in a decline in the potential choices for bakery products and poultry and an increase in the potential choices for fresh vegetables and cereals. The increasing consumer health risk information seems to have had no major impact on fresh fruits, processed fruits, and processed vegetables since their associated parameters are statistically insignificant.

As shown in Table 5, there exist no demographic variables that yield significant coefficients for all chosen healthy food groups. There may be insufficient variation in time series data to identify a more pronounced range of demographic effects on healthy food tastes.

Since we use monthly time series data, the seasonal changes in consumption of the selected healthy food groups are worth investigating. Two seasonal dummy variables such as Winter and Summer are incorporated into the modified LA/AIDS by the demographic translation method. Winter stands for November to February while Summer includes May through August. So the coefficient δ_{ik} associated with winter or summer dummy variables measure the effect on budget share w_i of a change in the season from the base months which are March, April, September, and October (spring and autumn) while holding other variables unchanged. The estimation results in the last two columns of Table 5 show that the coefficients of both seasonal dummy variables are significant at 5% level and contrary in signs between winter and summer for all seven groups. Therefore, there are seasonal fluctuations for the consumption of all selected healthy food groups.

The significant estimated parameters associated with summer have a positive sign for fresh fruits and fresh vegetables but a negative sign for processed fruits and processed vegetables. While the estimated coefficients associated with winter have a negative sign for fresh fruits and fresh vegetables but a positive sign for processed fruits and processed vegetables. The consumption for fresh fruits and fresh vegetables tend to be higher in summer and lower in winter. This may correspond to the seasonal changes in their prices and supply. The demand for processed fruits and processed vegetables is lower in summer when fresh fruits and fresh vegetables are cheaper and higher in winter when fresh fruits and fresh vegetables are more expensive. This may be viewed as evidence that the pair of fresh fruits and processed fruits and the pair of fresh vegetables and processed vegetables are substitutes. For cereals, bakery products, and poultry, the significant estimated seasonal parameters have the same sign as processed vegetables. That is, they have a negative sign for the summer but a positive effect for the winter. This indicates that the demands for staple food and poultry tend to be higher in winter and lower in summer. This is reasonable since winter has holidays to stimulate the consumption on bakery products and turkey, and people usually have poor appetite for meat and disserts in the summer.

Conclusions

The modified LA/AIDS model is apparently easy to estimate and permits testing of the theoretical restrictions in the neoclassical demand theory. More importantly, it is identical to the AIDS model that is grounded in a well-structured analytical framework at the point of normalization where elasticities are evaluated.

This paper analyzes the demand for seven selected healthy food groups based on the modified LA/AIDS by using proper price indices to improve the quality of approximation to the original nonlinear AIDS and obtain some remarkable results.

The estimated own price elasticities are close to unity for poultry and for fresh fruits and are much smaller than unity for all others. Poultry is the most price elastic while the cereals group is the least price elastic. Fresh fruits and fresh vegetables are more price elastic than processed fruits and processed vegetables. Larger expenditure elasticities for fresh vegetables and fruits indicate that increasing income would induce the increases in the consumption of fresh vegetables and fruits more than that of cereals and bakery products. The results of this study also suggest that cereals are less important staple foods relative to bakery products for the average household.

Fresh fruits and fresh vegetables are complements and they may be purchased and consumed together. The same conclusion can be made for the pair of processed fruits and processed vegetables, the pair of fresh fruits and processed vegetables, and the pair of bakery products and poultry. The pairs of fresh and processed fruits, fresh and processed vegetables, and cereals and bakery products are substitutes as the demand for one food group will increase if the price of the other increases.

All the demographic and health information variables in our study exhibit certain effects on the demand for some healthy food groups. The increase in consumer health risk information appears to have reduced the consumption of bakery products and poultry, but increased the consumption of fresh vegetables and cereals that contain relatively low fat. These results indicate that American consumers are conscious about diet and health and their concerns on fat and cholesterol have induced healthier diets.

This study also shows that seasonal fluctuations statistically exist in the consumption of all the food groups under study but the pattern of seasonal fluctuation for fresh fruits and fresh vegetables is the opposite to that for processed fruits, processed vegetables, cereals, bakery products, and poultry.

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Table 1. Likelihood ratio statistics for symmetry and homogeneity tests

Food Group	Fresh Fruits $\gamma_{i1} = \gamma_{1i}$	Fresh Veg. $\gamma_{i2} = \gamma_{2i}$	Processed Fruits $\gamma_{i3} = \gamma_{3i}$	Processed Veg. $\gamma_{i4} = \gamma_{4i}$	Cereals $\gamma_{i5} = \gamma_{5i}$	Bakery Products $\gamma_{i6} = \gamma_{6i}$	Poultry $\gamma_{i7} = \gamma_{7i}$	$\sum_{j=1}^{8} \gamma_{ij} = 0$
Fresh Fruits								0.14
Fresh Veg.	2.05							2.71**
Processed Fruits	1.59	4.77*						0.46
Processed Veg.	0.39	0.42	1.80					0.19
Cereals	0.17	3.57**	15.98*	5.49*				0.67
Bakery Products	2.05	2.09	12.57*	0.30	8.42*			2.34
Poultry	0.07	1.47	0.00	0.42	2.36	5.56*		0.00
Other Foods	2.79**	0.01	0.19	2.94**	20.60*	4.21*	7.94*	

Notes: Single, double asterisks (*) denote significance at 5% and 10% levels, respectively. The last column is the L.R. statistics for homogeneity test, and other entries are the L.R. statistics for symmetry test. The last row uses the adding-up condition for testing symmetry as the tests are based on $\gamma_{j8} = -\sum_{i=1}^{7}(\gamma_{ij})$, for $j = 1, \ldots, 7$.

Table 2. Parameter estimates of the constrained LA/AIDS, monthly data of 1981 – 1995

Parameter	Fresh Fruits	Fresh Veg.	Processed Fruits	Processed Veg.	Cereals	Bakery Products	Poultry	Other Foods
α_i	0.062*	0.039*	0.022**	0.026*	0.071*	0.126*	0.062*	0.591
	(2.55)	(2.20)	(1.71)	(2.07)	(4.08)	(5.48)	(2.41)	
β_i	-0.009**	-0.004	-0.004	-0.007*	-0.019*	-0.022*	-0.010**	0.075
	(1.66)	(1.09)	(1.47)	(2.56)	(5.06)	(4.45)	(1.83)	
γ_{i1}	0.006**	-0.002	-0.001	-0.002	0.009*	0.006	0.013*	-0.029
	(1.76)	(1.35)	(0.31)	(1.20)	(3.65)	(1.62)	(4.62)	
γ_{i2}		0.012*	0.001	0.006*	-0.001	0.004	0.001	-0.021
		(6.48)	(0.50)	(4.23)	(0.74)	(1.55)	(0.66)	
γ_{i3}			0.018*	-0.003	-0.018*	0.017*	-0.010*	-0.004
			(4.40)	(0.84)	(4.55)	(3.07)	(3.62)	
γ_{i4}				0.008	0.006	-0.010	-0.005**	0.0002
				(1.59)	(1.22)	(1.60)	(1.72)	
γ_{i5}					0.029*	0.018**	0.003	-0.046
					(3.15)	(1.66)	(0.88)	
γ_{i6}						0.031**	-0.009**	-0.056
						(1.93)	(1.94)	
γ_{i7}							0.003	0.003
							(0.61)	
R^2	0.64	0.42	0.32	0.59	0.84	0.67	0.47	
DW	2.09	1.76	1.64	1.84	1.75	1.74	1.53	

Notes: Single, double asterisks (*) denote significance at 5% and 10% levels, respectively. Parameters of other foods group were obtained by using adding-up condition. Numbers in parentheses are absolute t-values. The row of γ_{i8} and blank cells can be recovered by homogeneity and symmetry conditions, respectively.

Table 3. Budget shares and estimated uncompensated price and expenditure elasticities

Food Group	Budget Share	Uncompensated Price Elasticities								Expend. Elast.
		Fresh Fruits	Fresh Veg.	Proc. Fruits	Proc. Veg.	Cereals	Bakery Prod.	Poultry	Other Foods	
Fresh Fruits	0.033	-0.820	-0.065	-0.012	-0.062	0.290	0.188	0.407	-0.666	0.738
Fresh Veg.	0.032	-0.071	-0.614	0.026	0.184	-0.040	0.134	0.049	-0.541	0.873
Proc. Fruits	0.024	-0.019	0.036	-0.267	-0.112	-0.740	0.706	-0.410	-0.022	0.828
Proc. Veg.	0.018	-0.109	0.333	-0.144	-0.558	0.342	-0.532	-0.252	0.305	0.616
Cereals	0.033	0.302	-0.024	-0.532	0.192	-0.090	0.576	0.111	-0.960	0.424
Bakery Prod.	0.062	0.104	0.076	0.278	-0.156	0.298	-0.485	-0.139	-0.619	0.644
Poultry	0.029	0.469	0.061	-0.337	-0.159	0.119	-0.299	-0.883	0.377	0.653
Other Foods	0.767	-0.041	-0.030	-0.007	-0.002	-0.064	-0.079	0.001	-0.878	1.098

Notes: The figures for Budget shares are sample means. All elasticities are computed at sample means. Expend. Elast. = Expenditure Elasticity; Proc. Fruits = Processed Fruits; Proc. Veg. = Processed Vegetables; Bakery Prod. = Bakery Products.

Table 4. Estimated compensated price elasticities

Food Group	Fresh Fruits	Fresh Veg.	Proc. Fruits	Proc. Veg.	Cereals	Bakery Products	Poultry	Other Foods
Fresh Fruits	-0.796	-0.041	0.006	-0.049	0.315	0.235	0.429	-0.099
Fresh Veg.	-0.042	-0.586	0.047	0.200	-0.011	0.188	0.074	0.129
Proc. Fruits	0.008	0.063	-0.247	-0.097	-0.713	0.758	-0.386	0.614
Proc. Veg.	-0.089	0.353	-0.129	-0.547	0.362	-0.494	-0.234	0.777
Cereals	0.317	-0.011	-0.521	0.200	-0.076	0.602	0.124	-0.634
Bakery Products	0.125	0.097	0.293	-0.144	0.319	-0.445	-0.121	-0.125
Poultry	0.490	0.082	-0.321	-0.147	0.141	-0.259	-0.864	0.878
Other Foods	-0.004	0.005	0.019	0.018	-0.027	-0.010	0.033	-0.035

Table 5. Estimated parameters of demographic, health concern, and seasonal dummy variables

Food Group	Size (e^{-2})	Age (e^{-4})	Earners (e^{-2})	Stamps (e^{-5})	FCIM (e^{-3})	Win (e^{-3})	Su (e^{-3})
Fresh Fruits	0.73**	-1.71	-0.28	-1.48**	0.21	-1.66*	6.84*
	(1.70)	(0.47)	(0.51)	(1.67)	(0.55)	(2.73)	(11.24)
Fresh Veg.	0.93*	-0.34	-1.06*	-0.30	0.63*	-1.06*	1.89*
	(3.01)	(0.13)	(2.73)	(0.46)	(2.21)	(2.41)	(4.28)
Processed Fruits	-0.12	4.48*	0.23	-1.07*	-0.13	0.86*	-1.43*
	(0.55)	(2.31)	(0.76)	(2.26)	(0.58)	(2.64)	(4.48)
Processed Veg.	0.33	3.60**	-0.17	0.32	-0.18	1.15*	-2.78*
	(1.50)	(1.93)	(0.58)	(0.69)	(0.87)	(3.66)	(8.97)
Cereals	0.51**	5.60*	0.08	0.16	0.55**	0.95*	-2.27*
	(1.67)	(2.16)	(0.20)	(0.25)	(1.92)	(2.17)	(5.26)
Bakery Products	0.34	7.08*	-0.53	1.34	-1.15*	1.74*	-1.58*
	(0.84)	(2.06)	(0.99)	(1.59)	(3.02)	(3.00)	(2.76)
Poultry	1.08*	1.09	-1.53*	0.91	-0.07**	3.34*	-1.64*
	(2.39)	(0.28)	(2.68)	(0.96)	(1.74)	(5.22)	(2.55)

Notes: Single, double asterisks (*) denote significance at 5% and 10% levels, respectively. Numbers in parentheses are absolute t-values. Size = average family size; Age = average age of household head in years; Earners = Average number of wage earners; Stamps = average annual value of food stamps received by household; FCIM = the fat and cholesterol information index from MEDLINE database; Win = November, December, January and February; Su = May, June, July and August.