Consumer Demand for Healthy Diet: New Evidence from Healthy Eating Index

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Introduction

Promoting a healthy diet, such as increasing fruit and vegetable consumption, has been a global priority because of the scientific linkage between food intake and human health (Browe et al. 1966; Aldana et al. 2005;Bertsias et al. 2005;Allen 2006;Park et al. 2009). The U.S. Department of Agriculture (USDA) published a new food guidance system online in 2005 - "MyPyramid" - to help consumers make healthy food choices. Based on the Dietary Guideline for Americans released in 2005 and the food groups in MyPyramid, the USDA developed the new Healthy Eating Index (HEI), which was originally created by the USDA in 1995, to measure diet quality (Guenther et al. 2008).

Current literatures in nutrition and diet study have focused on determining the nutrient and dietary intakes among different groups and the impact of diet on consumer health (Eastwood et al. 1984;Vining 2008;Beydoun and Wang 2009;Park et al. 2009); on evaluating the dietary quality using certain type of indexes such as HEI (Schmidt et al. 2005;Breslow, Guenther and Smothers 2006;Angelopoulos et al. 2009;O'Neil et al. 2010); and on determining the relationship between diet cost and quality (Drewnowski and Darmon 2005;Lo et al. 2009). Economists have conducted extensive studies on consumer demand for food products such as fruits and vegetables (Price and Mittelhammer 1979;Heien and Wessells 1990;Pollack 2001), meats (Chavas 1983;Haley 2001) and beverage (Heien and Pompelli 1989;Brown, Behr and Lee 1994). It seems there is a gap between nutritional studies on diet and economic analysis of demand for a healthy diet (diet quality). Although the studies by Lee (1987) and Shonkwiler, Lee and Taylor (1987) and Duffey et al. (2010) try to determine the impact of food prices on demand for the quality of diet, they did not have an exact measure of diet quality. For instance, Lee (1987) and Shonkwiler, Lee and Taylor (1987) use the variety of food as proxy of diet quality. Duffey et al. (2010) treat daily energy intake as a measurement of diet quality, and they only study demand for soda, whole milk, burger and pizza. The fact that there are few studies addressing the cost of, and consumer demand for diet quality is likely the results of the lack of a good measure of healthy status of diet and the unavailability of the food prices corresponding to numerous food items in consumer diet.

The HEI that measures the healthy status of a diet was initially developed in 1995, and new index based on 2005 Dietary Guidelines for Americans was developed in 2006. However, the unavailability of food prices that match the foods used in calculating HEI still creates barriers to estimate the cost of and consumer demand for a healthy diet. In 2009, the Center for Nutrition Policy and Promotion (CNPP) published the Food Price Database of 4,600 foods in "as consumed" forms for 2003-2004 (USDA-CNPP 2009). The foods in the database match those reported by respondents in Dietary Interview-Individual Foods and Dietary Interview-Total Nutrient Intakes of National Health and Nutrition Examination Survey (NHANES, CDC 2007). This enables us to estimate the cost of accessing a healthy diet and consumer demand for diet quality. We expect the results in this paper will help us understand the cost of accessing a healthy diet and shed light on policies and programs that endeavor to promote healthy food consumption among U.S. consumers.

The Health Eating Index

The HEI is developed to evaluate the diet quality of individual of ages of 2 years and older. It consists of 12 individual indexes of Total Fruit, Whole Fruit, Total Vegetable, Dark Green and Orange Vegetables and Legumes, Total Grain, Whole Grain, Milk and Milk Products, Meat and Beans, Oils, Saturate Fat, Sodium and Calories from Solid Fats, Alcoholic beverages and Added Sugars (SoFAAS). Based on individual food consumption, the nutrient intake is transform through the a system of linear equations such as $B \cdot q = t$, where B is a matrix defines the relationship between food intake q and nutrient intakes, t; i.e., the 12 diet groups in MyPyramid that are used to evaluate diet quality. With the nutrient intakes t, a set of functions f defines the relationship between nutrient intakes and diet quality z or HEI.

Individual nutrient intakes are first transformed into a base of 1,000 calories for diet groups 1 to 9 and 11. For the nutrient intakes of the first 9 diet groups, the intakes of different groups are compared with the corresponding recommended intake of that group. If the nutrient intakes from a diet group, say Total Fruit meets the recommended quantity, it will receive the maximum HEI score of that group. If the nutrient intake from a diet group is zero, that group gets a zero HEI score. Intakes between zero and the recommended quantity (maximum level) are scored proportionately. For the 11th diet group, Sodium, the maximum score is received if the Sodium intake is less than the recommended amount. For diet groups such as Saturated Fat and SoFAAS, the HEI scores are received based on the percentage of energy obtained from those groups to the total energy from food consumption. If the energy from Saturated Fat is less or equal than 7% of the total energy from the food consumption, the Saturated Fat diet group receives highest HEI score. If the energy from SoFAAS is less than or equal to 20% of the total energy, the SoFAAS diet group gets the highest HEI score (for more details, see Guenther et al. 2007;Patricia, Jill and Susan 2008).

The maximum HEI scores of different diet groups vary. The first six food groups receive the maximum HEI scores of 5, the SoFAAS group receives a maximum score of 20, and the rest diet groups receive maximum scores of 10. The total score ranging from 0 to 100 is simply the sum of all individual HEI scores and can be used to assess the overall diet quality of a individual's food consumption. A higher HEI score indicates better diet quality. The HEI has been used to evaluate diet quality among various consumer groups (Pick et al. 2005;Angelopoulos, et al. 2009;O'Neil, et al. 2010). Some studies have found a negative relationship between HEI and some healthy problems, implying the effectiveness of using the HEI to assess diet quality (Kennedy et al. 2001;Guo et al. 2004;Weinstein, Vogt and Gerrior 2004;Ford, Mokdad and Liu 2005;Reedy et al. 2008)

Economic Model

Based on the household production theory (Deaton and Muellbauer 1980), households chose marketable foods to produce a nonmarketable diet on which they maximize the utilities. Assume that the vector $z=(z_1, z_2, \ldots z_g)$ represents diet quality of g diet groups that affect consumer utility levels. Consumers are assumed to produce the nonmarketable diet quality through the purchase of marketable foods, $q=(q_1, q_2, \ldots q_n)$ at market prices $p=(p_1, p_2, \ldots p_n)$. Given the fact that consumer's choice of foods in the market will result in various diet combinations, the transformation of q into z can be represented by the household production function such that $h(q, z)=0$. With the assumption that food consumption is weakly separable from all other commodity groups, consumer food choice may be modeled through two stages. In the first stage, the consumers will try to minimize the total cost of achieving a certain level of diet quality z by choosing marketable foods q, subject to the technology constraint such that

(1) $Min\ C=p.q$

$s.t.\ h(q, z)=0.$

The result is the cost function

(2) $C^0=C(p, z)$

that defines the minimum cost of obtaining a given level of healthy diet z for any given price vector p. In the case of diet quality, the household production function is a system of linear equations that define the relationship between food consumption and diet qualities. Based on the calculation of HEI, the household production function can be defined as:

$B \cdot q = t$ and $z=f(t)$

where B is a m by n matrix that defines the transformation from food consumptions to nutrient intakes, q is a column vector (n by 1) of food consumption, and t is a column vector (m by 1) of nutrient intakes. Based on the amount of nutrient intakes, the diet quality z is obtained by a set of functions that defines the relationship between nutrient intakes and diet qualities. Because of the linear relationship between food consumption and nutrient intake, the nutrient intake z is a non-decreasing function of cost. However, this is not true for diet quality z - the diet quality is based on the relative intakes of nutrient rather than the absolute amount of nutrient intakes. For instance, the HEI score is based on the nutrient intake from one diet group per 1,000 calories. In addition, the intakes of Saturated Fat, Sodium and SoFAAS have negative relationships with diet quality, because of the health risk related to the excessive intake of those diet groups. Therefore, there is a nonlinear or some time inverse relationship between nutrient intakes and diet qualities. The cost function $C=C(p, z)$ may not have the property of non-decreasing in z that normally governs the cost function in microeconomic theory (Mas-Collell, Whinston and Green 1995).

The shadow prices of the nonmarketable diet group z_i can be calculated directly as:

(3) $\pi_i = \partial C/\partial z_i,\ i=1,\ldots,m.$

Given the shadow prices of various dietary groups, the second stage problem for consumer is to

(4) $Max\ u(z)$ subject to $C^0=g(\pi,z)$,

where u is the well defined utility function. The implicit solution of the optimization problem is

(5) $z_i=z_i(C^0,\pi)$,

which may be considered as consumer demand for the diet quality of various diet groups. With the estimates of shadow price π and expenditure C^0, the demand for, as well as the price elasticities of diet quality z can be obtained by estimating the demand system specified in $z_i=z_i(C^0,\pi)$.

The Data

Data on two-day food consumption and nutrient intakes for 2003-2004 are obtained from the NHANES databases, including data of Dietary Interview of Individual Foods (DIIF) and Dietary Interview of Total Nutrient Intakes (DITN). DIIF provide detailed information on the types (corresponding to USDA food codes) and amount (in gram) of foods and beverages consumed by NHANES participants in two days. DITN has the information on individual nutrient intakes based on the data from DIIF and USDA Food and Nutrient Database for Dietary Studies (FNDDS,USDA-ARS 2006). The FNDDS provides information on nutrient values of each food listed in USDA food codes. The nutrient information helps transform individual food intake to nutrient intakes. The total calorie intake from food consumption from DITN is used to transform the nutrient intakes from absolute amount into intakes per 1,000 calories. The MyPyramid Equivalents Database (Bowman, Friday and Moshfegh 2008) is used to transform individual food and nutrient intakes into cup or ounce equivalents of diet groups corresponding to those in Dietary Guideline for Americans, 2005, which helps calculate the HEI of different diet groups to measure the diet qualities. In addition, the foods listed in 2003-2004 CNPP Food Prices Database[i] matches with the foods in DIIF which enables us to calculate the expenditure on marketable food *q* for each individual in NHANES. Based on the classification of food groups in the FNDDS, the foods of nine major food groups are aggregated into five marketable food groups. This aggregation avoids the problem of zero consumption and expenditure of certain food groups, which may create problems when calculate the unit expenditure on foods (prices of food paid by individual). The five marketable food groups include Fruit and Vegetable (FV, aggregation of fruits group and vegetable group), Fats and Sugar (FS, aggregation of fats, oils, and salad dressing group and sugars, sweets and beverages group), Meat, Egg and Beans (MEB, aggregation of meat, poultry, fish and mixtures group, eggs group and legumes, nuts, and seeds group), Milk and Milk Products (MILK, milk and milk product group) as well as Grains group (GRAIN, grain products group). Unit expenditure (price of) on each food group can be calculated as the ratio of expenditure on certain food group to total gram consumption of corresponding food group. Therefore, we obtain the quantity (*q*) and price (*p*) of given food groups that the consumer purchased in the market and the nonmarketable products (z) which is the HEI that measures diet quality.

Empirical Analysis

For respondents of ages equal or greater than 20 years in the NHANES, HEI scores are calculated based on the average food consumptions in two days. Respondents younger than 20 years were removed from the analysis based on the assumptions that most individuals of ages 20 years or older will make their own food choice decisions, thus reflecting the demands for healthy diet of the real decision makers. Because no prior information on the cost function is available, we estimated a translog cost function. Translog cost function has some nice properties and has been widely used in many empirical analyses (Caves, Christensen and Swanson 1980; Cowing and Holtmann 1983; Shonkwiler, Lee and Taylor 1987). The translog cost function is specified as:

(6) $lnC = \alpha_0 + \sum_i^n \alpha_i lnp_i + \sum_j^m \beta_j lnz_j + 1/2 \sum_i^n \sum_j^n \alpha_{ij} lnp_i lnp_j + 1/2\ \sum_i^m \sum_j^m g_{ij}\, lnz_i\, lnz_j + \sum_i^n \sum_j^m \gamma_{ij}\, lnp_i\, lnz_j$

where C is the individual average expenditure on foods in two days; p is the unit price of marketable foods; z is HEI measuring the diet quality; n=5 for the five marketable food groups; m=12 for the HEI of 12 diet groups. To avoid the problem of taking the log of zero HEI scores for some HEIs, we added one to each HEI[ii]. This shifts the minimum score of HEI from zero to 1, but is still consistent with the original HEI. Theoretical restrictions such as homogeneity ($\sum_i^n \alpha_{ij} = 0$, $\sum_i^n \alpha_i = 1$,$\sum_i^n \sum_j^m \gamma_{ij} = 0$), and symmetry ($\alpha_{ij} = \alpha_{ji}$, $g_{ij} = g_{ji}$) can be easily imposed.

In general, curvature condition such as concavity on input prices cannot be imposed globally on translog cost function. This is because the hessian matrix of a translog cost function is not simply the parameters of the cost function like that in a normalized quadratic cost function. However, if the shares of inputs are not negative, negative semidefinite property of parameters in matrix A (where A consists of the parameters of $lnp_i lnp_j$) is the sufficient condition to impose global concavity on input prices (Diewert and Wales 1987). This approach, on this other hand, will lead the cost function being “too negative semidefinite”, thus result in upward biased estimation of cross price elasticities (Diewert and Wales 1987,p48). Ray and Wales (2000) develop an approach to impose concavity in translog cost functions at a single observation that may result in concavity at many points. This approach maintains the flexibility of the translog cost function. We use the second approach because of concern with the biased estimation of substitution effects between inputs that may results from imposing globally concavity. To impose the concavity at a single point, an observation is chosen as a base point. Input prices are then normalized with the corresponding prices of the base point. Concavity is imposed by letting

(7) $\alpha_{ij} = -(UU^{'}) + \alpha_i \delta_{ij} - \alpha_i \alpha_j \;\; i, j = 1, \dots, n,$

where U is a triangular matrix. In the estimation, α_{ij} in equation (6) is replaced by the right hand side of equation (7), which will guarantee that concavity is satisfied at the selected single point (the base point)

According to Shephard's Lemma, share equations are derived such that:

(8) $w_i = \frac{p_i q_i}{C} = \frac{\partial lnC}{\partial lnp_i} = \alpha_i + \sum_j^n \alpha_{ij} lnp_j + \sum_j^m \gamma_{ij} \, lnz_j, \;\; i = 1, \dots, n.$

The cost function in equation (6) together with the four share equations represented by equation (8) is estimated using full information maximum likelihood method. One of the share equations is removed in the estimation process to avoid the singularity problem. With the share equation, the own price elasticity and cross price elasticity of demand for marketable goods q_i can be calculated as $\varepsilon_{ii} = \frac{\alpha_{ii}}{w_i} + w_i - 1$, and $\varepsilon_{ij} = \frac{\alpha_{ij}}{w_i} + w_j$, respectively. The shadow price of the healthy diet z, or HEI is estimated as

(9) $\pi_j = \frac{\partial lnC}{\partial lnz_j} \frac{C}{z_j} = \left(\beta_j + \sum_i^m g_{ij} lnz_i + \sum_i^n \gamma_{ij} \, lnp_i\right) \cdot \frac{C}{z_j}, \;\; j = 1, \dots, m$

Demand for a healthy diet as equation (5) is estimated as a linear function of shadow prices and quadratic function of food expenditure (Shonkwiler, Lee and Taylor 1987), together with demographic variables as demand shifters, such as:

(10) $z_j = \theta_0 + \sum_i^m \theta_i \pi_i + \lambda_1 C + \lambda_2 C^2 + \sum_i^k \omega_i D_i, j = 1, \dots, m$.

where π_i is shadow price; C is the individual average expenditure on foods in two days; D is demographic variables such as age, gender etc. A system of 12 equations is estimated using seemingly unrelated regressions[iii].

Results

Consumption of Foods and HEI Scores

The analysis is based on 3,875 respondents who were 20 years old or older, these respondents account for about 54 percent of the total respondents in the NHANSE 2003-04 data. The mean age of the respondents is 51 years, and the mean value of Poverty Income Ratio (PIR) is 2.62. The PIR is the ratio of income to the household poverty threshold based on the household size. PIR ranges from 0 to 4.99 and topped at 5. About 31% of the respondents in the sample have PIR below or equal 1.3, which may be considered as below poverty line[iv]. Males account for 47% of the sample; non-Hispanic, White, non-Hispanic black and Mexican American account for 56%, 18% and 21% of the sample, respectively; and more than 72% of the respondents had high school or college education (Table 1).

Among the five food groups, the consumption of fat and sugar is the highest, about 1.9 kilogram (kg)/day. The consumption of milk and milk products, meat, egg and bean, grain, and fruit and vegetable are 0.5, 0.6 and 0.7 kg per day, respectively. The average daily food expenditure is about $4.32, with the highest and lowest spending of $0.39 and $18.35, respectively. The expenditure on milk and milk products is the lowest, about $0.47 per day, followed by the spending on fat and sugar ($0.57). Consumers spend the most money on meat, egg and beans ($1.47), followed by grain products ($0.94), and fruit and vegetable ($0.86).

Because of the large quantity and low expenditure on fat and sugar food group, the average price of fat and sugar is the lowest, about $0.37/kg. Meat, egg and bean food group has the highest price of $2.92/kg, followed by grain product ($1.60/kg), milk and milk products ($1.41/kg) and fruit and vegetable ($1.29/kg).

The average total HEI score is 56.21. SoFAAS food group receives the highest score of 10.46 and whole grain food group receives the lowest score of 1.17 (table 1). However, because the maximum HEI scores of different diet groups are different, the relative score of the ratio between HEI score and the maximum sore that can be obtained by a corresponding diet group will provide more information on the diet quality. The ratio between HEI score and the maximum score of Whole Grains is the lowest, about 0.23. It implies that consumer consumption of whole grain products is about 77% lower than the optimal level that is recommended by 2005 Dietary Guideline for Americans. Another diet group that has insufficient intake is Dark green & Orange Veg & Legumes, which has a ratio of 0.29. The consumption of Total Grain and Meat & Beans are most close to the optimal level- the ratios of both groups are about 0.89. Sodium is among the three diet groups that have a ratio less than 0.5, which indicates the over consumption of sodium among respondents.

Estimates of Cost and Share Equations

Following Ray and Wales (2000), the cost and share equations are estimated with concavity imposed at a single point. To determine the base point that is used to normalize the food prices, the cost and share equations are estimated without concavity imposed. This give 1,485 observations at which own price elasticities are negative. We then use each of the 1485 observations as the base point to estimate the models, and check the concavity for all the observations. The final model is selected such that the proposition of observations that satisfy the curvature conditions is the highest. In the final model, the concavity condition is satisfied at 2,741 observations, about 71% of the total observations used in the model.

Table 4 reports the estimates of the parameters of the translog cost function and the share equations. The estimates of the parameters of food prices ($\alpha_i, i = 1 - 4$) are all significant at 5% significance level, and most parameters of the interactions of food prices and HEIs ($\gamma_{ij}, i = 1 - 4, j = 1 - 12$) are significant at 5% significance level. None of the estimates of the parameters of HEIs ($\beta_i, i = 1 - 12$) are significant, and only a few estimates of the parameters of interaction between HEIs ($g_{ij}, i = 1 - 12, j = 1 - 12$) are statistically significant at 5% or 10% significance level. The significance of γ_{ij} implies that diet quality affects the budget share of different food groups. For instance, $\gamma_{11} = -0.014$ indicates that if the diet quality of Whole Fruit increase by one percent, the budget share of food group Milk and Milk Products will decrease by 1.4% points. Among the 48 estimates of γ_{ij}, more than half are negative, implying that increasing the HEI score (diet quality) of certain diet group will result in increasing expenditure on foods containing high level nutrients for that diet group, thus reduce the spending on other food groups. Results also shown that estimates of $\gamma_{i12,}$ $i = 1 - 4$ are all statistically significant and positive, which implies that the improved diet quality in SoFAAS increases the budget share of foods of FV, MEB, MILK and GRAIN. This is partially because that improving diet quality in SoFAAS requires fewer intakes of calories from Solid Fats, Alcoholic beverages and Added Sugars.

The price elasticities of demand for food groups shown in Table 5 are the means of the elasticities calculated at each observation. All the own price elasticities are negative and the cross price elasticities are positive. The negative own price elasticities is a natural consequence of imposing concavity on input prices and the concavity conditions being satisfied at most of the observations. The positive cross-price elasticities imply that all the food groups are substitutes – an increase in the price of one food group will results in an increase in the demand for other groups of foods. All own-price elasticities are less than unity, implying inelastic demand for food. Most of the own-price elasticities are statistically significant at 5% significance level. The only four elasticities that are not significant are own price elasticity of FV, cross-price elasticity of MEB with respect to MILK, cross-price elasticity of FV with respect to GRAIN and cross-price elasticity of FS with respect to FV. The estimate of parameters of MILK has the largest magnitude, which means that policies such as tax or subsidy on diary product may have largest economic impact on the consumption of milk and milk products. In addition, the cross-price elasticities of Milk, MEB, GRAIN and FV with respect to FS have larger magnitudes compared to their cross-price elasticities with respect to other foods. This implies that policy instruments that are used to improve health food consumption may have larger impact on the consumption of FS than on the consumption of other foods.

Demand for Healthy Diet

The shadow prices for each HEI are calculated for every respondent in the sample using equation (9). Table 6 reports the means and standard deviations of the estimates of shadow prices for the 12 HEIs. All the shadow prices are significant at 5% significance level. The mean shadow price of HEI4 (Dark Green &Orange Veg & Legumes) is the highest ($0.80), followed by shadow price of HEI1 (Total Fruit, $0.56). This indicates that consumers are most willing to pay premiums to improve the diet quality of Dark Green and Orange Vegetable and Legumes. Consumers are willing to pay about $0.56 to obtain one unit increase the HEI of diet group of

Total Fruit. The negative shadow prices of some HEIs such as HEI of Total Grains, Meat and Beans as well as SoFAAS may be the results of not imposing monotonicity on the cost function. However, not imposing monotonicity is a reasonable action because in the case of diet quality, increasing nutrient intakes does not necessarily improve the diet quality and in some cases, may impair consumer diet quality. For instance, more intakes of SoFAAS will result in a decrease in HEI of SoFAAS. The violation of *Free Disposal* property (Mas-Collell, Whinston and Green 1995,p131) in the production of diet quality makes it possible that cost function is decreasing in the HEI. The negative shadow prices of HEI5 (Total Grain), HEI8 (Meat and Beans) and HEI12 (SoFAAS) imply that consumer are not willing to pay the improvement of diet quality of those three diet groups or simply means that the increasing in the HEI of those three groups will decrease the cost of food consumption.

The estimates of a system of demand equations for diet quality are reported in table 8. In the estimation, dummy variables are created for categorical demographic variables such as gender, marital status, education and ethnicity (table 1). The dummy variable of the last category of each demographic variable is removed to avoid dummy trap. Results show that overall the shadow prices of HEI significantly affect consumer demand for diet quality. The only two exceptions are shadow prices of HEI8 and HEI9. The shadow prices of diet quality of Oil (HEI8) and diet quality of Saturated Fat (HEI9) do not have significant impact on consumer demand for diet quality of Whole Fruit (HEI2), Total Vegetable (HEI3), Dark Green & Orange Veg & Legumes (HEI4), Total Grains (HEI5) and Whole Grains (HEI6). This implies that consumer demand for diet quality of those five groups may be independent of the price of diet quality of Oil. The expenditure on food consumption, significantly affects the demand for HEI5 - HEI7 and HEI9 - HEI12, but does not significant affect the demand for HEI1-HEI4 and HEI8. This means that consumer demands for diet quality of Total Fruit (HEI1), Whole Fruit (HEI2), Total Vegetable (HEI3), Dark Green & Orange Veg & Legumes (HEI4), and Meat & Bean (HEI8) are persistent—they are less likely to change due to substantial change in food expenditures.

Age, though with small scale, significantly affect consumer demand for diet quality, and for most diet quality, those impacts are positive (HEI1-HEI6, HEI9 and HEI12). However, diet quality of Milk & Milk Products (HEI7) and Saturated Fat (HEI10) of older people are significantly worse than younger people. A simple correlation shows that the consumption of marketable food group MILK has a positive relationship with HEI7 and negative relationship with HEI10. This may imply that the under consumption of food of MILK by older people may be because of concern with saturate fat in milk and milk products. However, by avoiding the saturated fat in the milk and milk product, older people obtained too much calories from other food sources that are high in saturated fat. Overall, the demands for diet quality of all diet groups of male are significantly less than those of female, with the exception of demand for HEI8 (Meat & Bean), which indicate that male are more likely to obtain more nutrient from the consumption of meat than from other foods. The estimates of Eth1 (Non-Hispanic White) of six equations (HEI1, HEI4, HEI8, HEI10-HEI12) are significant and negative at 10% significance level indicating that Non-Hispanic White demand less for quality in those diet groups than the base consumer group of Other Hispanic. Non-Hispanic White consumers demand more for quality in diet groups of Milk & Milk Products (HEI7) and Oils (HEI9). Non-Hispanic Black demands less for HEI2, HEI5, HEI7, HEI10 and HEI12, but significantly more for diet quality of Oils. Overall, the demands for diet quality of Mexican American, and Other Race-Including Multi-Racial are not significantly different from the demands of Other Hispanic consumers. The coefficients of PIR of all 12 equations except for the equation of Z8 (HEI8) are not statistically significant, which means that poverty level or household income does not have a significant impact on consumer demand for diet quality. Interestingly, education level has much more influential impact on the demand for diet quality. Compared to people with College Graduate or Above degree, other consumers are less likely to care about the diet quality of Total Fruit, Whole Fruit, Total Vegetables, Dark Green & Orange Veg & Legumes, Whole Grains, Saturated Fat and SoFAAS, however, they demand more for the diet quality of Meat & Beans.

The own- and cross-price elasticities and expenditure elasticities of demand for diet quality are calculated for each individual in the sample and their sample means are reported in table 8. Most of the elasticities are statistically significant at 5% significance level except the own price elasticity of HEI8 (Meat & Beans) and the cross price elasticity of HEI12 (SoFAAS) and HEI6 (Whole Grains). The absolute values of all elasticities are less than unity, indicating inelastic demand for diet quality. HEI4 (Dark Green & Orange Veg & Legumes) has the largest own price elasticity (-0.88) followed by HEI11 (Sodium, -0.81), HEI1 (Total Fruit, -0.71) and HEI2 (Whole Fruit, -0.68), which means that consumer demand for diet quality of Dark Green & Orange Veg & Legumes, Sodium, Total Fruit and Whole Fruit are more sensitive to the price changes of those HEIs. Overall, the cross-price elasticities are smaller than the own-price elasticities, implying that the demand for diet quality are more responsive to the own- price change than the price changes of diet quality of other diet groups. Compared to other diet groups, the cross price elasticities between most HEIs and HEI12 have larger scale and are negative. This means that the price change of diet quality of other diet groups will have large impact on the demand for the diet quality of SoFAAS. However, the cross-price elasticities between HEI12 and most HEIs are close to zero, indicating that the price change of diet quality of SoFAAS does not have large impact on the demand for quality of other diet groups. This asymmetry in the cross price elasticities between HEI12 and other HEIs means that policy instruments that targeting the price change of HEI12 may be effective in deceasing calories from SoFAAS while at the same time, improving or keeping unchanged the diet quality of other diet groups.

Among the 12 expenditure elasticities, five of them are negative. This includes the expenditure elasticities of diet quality of Total Grain (HEI5), Whole Grain (HEI6), Meat &Bean (HEI8), Saturate Fat (HEI10), and SoFAAS (HEI12), which implies that with more expenditure on foods, in their total diet consumers obtain less nutrient from Total Grain, Whole Grain, Meat & Bean, however, more nutrient from Saturate Fat and SoFAAS. This result also may reflect the fact that more expenditure on foods are used for foods that are more nutritious in the nutrient of fruit, vegetable, milk and milk products as well as oils.

Conclusion

Promoting health diet has been one of the first priorities of many countries. In the U.S. consumers are encouraged to consume more fruit and vegetable to improve the overall diet quality which is currently heavy in meat and dairy products. Large body literature has studies the connection between diet and health problems and the USDA has continuously worked on providing scientific information on the healthy food consumption using various programs such as MyPyramid. The HEI developed based on 2005 Dietary Guideline for Americans, similar to that of MyPyramid enable us to have accurate measure of an individual’s diet qualities. The HEI, though has been used to investigate diet quality of different population, has not be employed to study consumer demand for quality of diet. This may be the results of lacking price information on the foods that are used to calculate the HEI. In this paper, we make use the new published price data by CNPP, and based on the household production theory, systematically study consumer demand for diet quality.

Our results show that Fat and Sugar has the lowest price among the five marketable food groups, only 12.7% of the price of Meat, Egg and Bean. Insufficient consumption of Whole Grains and of Dark Green & Orange Veg & Legumes in the diet may be the biggest problem facing the U.S. consumers. Consumes are most liking to pay price premium for the diet quality of Dark Green & Orange Veg & Legumes. They are not willing to pay for the diet quality of Total Grains, Meat & Beans and SoFAAS (Calories From Solid Fat, Alcohol & Added Sugar). However, because the shadow prices of diet quality equal marginal costs, consumers may improve their diet quality of those three diet groups without extra food expenditures. Similar to some studies, our results confirm that income does not have a significant impact on consumer food consumption - their demands for diet quality are invariant to the household income and to poverty level. Males are less concern about the quality of all diet groups except Meat and Beans and older people are more careful in their food selections by demanding more for diet quality of most of the diet groups. Education has a significant impact on consumer selection of diet - consumers with college degree above are more concerned with the quality of all diet groups except diet quality of Meat and Beans. This may be because that people with higher level of education have more access to the information on the health benefits of food consumption. And people with more education are more likely to obtain and better interpret nutrient information of foods.

The results of this study may provide critical and valuable information to policy makers and stakeholder that are targeting the improvement of the diet qualities. It can be further extent to study the linkage between the demands for diet quality and individual health problem such as obesities.

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Table 1 Respondent Demographics of the Sample

Demographic Variable	Statistics
Age	51.03[a] (19.55)[b]
PIR	2.61[c] (1.59)
Gender	
Male	47.10%
Marital Status	
Marriage1: Married	55.47%
Marriage2:Windowed	11.23%
Marriage3: Divorced	9.37%
Marriage4: Separated	2.56%
Marriage5: Never Married	15.2%
Marriage6: Living with partner	6.17%
Education	
Edu1: Less than 9th Grade	13.83%
Edu2: 9-11 Grade	14.55%
Edu3: High School Grade/GED or Equivalent	24.46%
Edu4: Some College or AA Degree	27.69%
Edu5: College Graduate or Above	19.46%
Ethnicity	
Eth1: Non-Hispanic White	56.03%
Eth2: Non-Hispanic Black	17.63%
Eth3: Mexican American	20.52%
Eth4: Other Race-Including Multi-Racial	2.81%
Eth5: Other Hispanic	3.02%

Notes:
a: Mean age of 3,875 respondents in the sample.
b: Numbers in parentheses are standard deviations.
c: Mean age of 3,670 respondents in the sample, because of the missing information of some respondents.

Table 2 Food Consumption, Expenditure and Unit Price

	Consumption (kg)	Expenditure ($)	Unit Price ($/kg)
Milk and Milk Products	0.50[a]	0.47	1.41
	(0.53)[b]	(0.43)	(1.09)
Meat, Egg and Bean	0.53	1.47	2.92
	(0.37)	(1.10)	(1.27)
Grain Products	0.60	0.94	1.60
	(0.42)	(0.83)	(0.79)
Fruit and Vegetable	0.72	0.86	1.29
	(0.54)	(0.68)	(0.71)
Fat and Sugar	1.93	0.57	0.37
	(1.44)	(0.48)	(0.46)
Total	4.29[c]	4.32[d]	
	(1.83)	(1.91)	

Notes:
a: Mean values of 3,875 respondents in the sample.
b: Numbers in parentheses are standard deviations.
c: Mean value of total food consumption.
d: Mean value of total food expenditure.

Table 3 HEI Score of Total and Individual Food Group

Variable	Descriptive	Mean	Std[a]	HEI/HEI Max
HEI	TOTAL HEI-2005 SCORE	56.21	13.31	0.56
HEI1	TOTAL FRUIT	2.67	1.96	0.53
HEI2	WHOLE FRUIT	2.57	2.15	0.51
HEI3	TOTAL VEGETABLES	3.34	1.42	0.67
HEI4	DARK GREEN & ORANGE VEG & LEGUMES	1.47	1.70	0.29
HEI5	TOTAL GRAINS	4.45	0.89	0.89
HEI6	WHOLE GRAINS	1.17	1.42	0.23
HEI7	MILK & MILK PRODUCTS	5.33	3.05	0.53
HEI8	MEAT & BEANS	8.88	1.93	0.89
HEI9	OILS	6.07	3.12	0.61
HEI10	SATURATED FAT	5.86	3.31	0.59
HEI11	SODIUM	3.94	2.82	0.39
HEI12	CALORIES FROM SOLID FAT, ALCOHOL & ADDED SUGAR (SoFAAS)	10.46	5.96	0.52

Note:
a: Standard deviations.

Table 4 Parameter Estimates of Translog and Share Equations

Coefficient	Estimate	Coefficient	Coefficient	Coefficient	Estimate
α_0	10.19[a]	g_{34}	1.83*	g_{1111}	-0.71*
α_1	0.95*	g_{35}	0.80	g_{1112}	0.06
α_2	1.35*	g_{36}	-0.30	g_{1212}	0.29
α_3	0.80*	g_{37}	-0.59**	γ_{11}	-0.14*
α_4	1.00*	g_{38}	-0.06	γ_{12}	0.13*
β_1	1.59	g_{39}	0.12	γ_{13}	-0.32*
β_2	-0.17	g_{310}	0.46**	γ_{14}	0.05*
β_3	4.02	g_{311}	-0.56*	γ_{15}	-0.22*
β_4	-1.70	g_{312}	0.05	γ_{16}	0.05*
β_5	2.40	g_{44}	-3.52*	γ_{17}	1.12*
β_6	-0.01	g_{45}	0.12	γ_{18}	-0.29*
β_7	0.32	g_{46}	0.27	γ_{19}	-0.08*
β_8	5.02	g_{47}	0.10	γ_{110}	-0.20*
β_9	0.80	g_{48}	0.34	γ_{111}	0.15*
β_{10}	-1.87	g_{49}	0.28	γ_{112}	0.14*
β_{11}	1.61	g_{410}	-0.01	γ_{21}	-0.27*
β_{12}	1.90	g_{411}	0.02	γ_{22}	-0.03
μ_{11}	-2.70*	g_{412}	-0.22	γ_{23}	-0.43*
μ_{12}	0.03	g_{55}	-6.84*	γ_{24}	0.12*
μ_{14}	-1.13	g_{56}	1.11	γ_{25}	-0.56*
μ_{23}	1.09	g_{57}	1.68*	γ_{26}	-0.16*
μ_{13}	2.12*	g_{58}	1.10	γ_{27}	-0.47*
μ_{22}	-0.27	g_{59}	0.33	γ_{28}	1.24*
μ_{24}	0.22	g_{510}	1.08*	γ_{29}	-0.19*
μ_{33}	1.19	g_{511}	-0.41	γ_{210}	-0.05*
μ_{34}	1.14	g_{512}	-1.21*	γ_{211}	-0.17*
μ_{44}	0.82	g_{66}	-2.71*	γ_{212}	0.37*
g_{11}	-1.90*	g_{67}	-0.20	γ_{31}	-0.15*
g_{12}	1.72*	g_{68}	-0.53	γ_{32}	0.03**
g_{13}	-0.06	g_{69}	0.29	γ_{33}	-0.07*
g_{14}	0.52**	g_{610}	-0.13	γ_{34}	-0.03**
g_{15}	-0.36	g_{611}	-0.18	γ_{35}	0.86*
g_{16}	-0.37	g_{612}	0.61*	γ_{36}	0.01
g_{17}	-0.14	g_{77}	0.52	γ_{37}	-0.04*
g_{18}	-0.29	g_{78}	-0.88	γ_{38}	-0.29*
g_{19}	0.35	g_{79}	0.10	γ_{39}	-0.09*
g_{110}	0.35	g_{710}	-0.05	γ_{310}	0.03*
g_{111}	0.11	g_{711}	0.16	γ_{311}	-0.04*
g_{112}	0.07	g_{712}	-0.21	γ_{312}	0.06*
g_{22}	-5.67*	g_{88}	-2.43*	γ_{41}	1.07*
g_{23}	-0.07	g_{89}	0.22	γ_{42}	-0.04
g_{24}	-0.03	g_{810}	-0.09	γ_{43}	1.12*
g_{25}	0.70	g_{811}	0.19	γ_{44}	0.04**

g_{26}	0.53*	g_{812}	-0.46	γ_{45}	-0.40*
g_{27}	0.50*	g_{99}	-1.19*	γ_{46}	0.14*
g_{28}	0.39	g_{910}	0.17	γ_{47}	-0.21*
g_{29}	-0.24	g_{911}	0.03	γ_{48}	-0.48*
g_{210}	-0.03	g_{912}	-0.08	γ_{49}	-0.16*
g_{211}	0.05	g_{1010}	-0.10	γ_{410}	-0.01
g_{212}	0.01	g_{1011}	0.04	γ_{411}	0.04**
g_{33}	-3.30*	g_{1012}	-0.18	γ_{412}	0.21*
No. of Obs.			3875		
Log Likelihood			16479.82		
Adjusted R^2	LC	W_1	W_2	W_3	W_4
	0.19[b]	0.46[c]	0.4	0.35	0.54

Notes:
One * indicates statistically significant at 5% significance level.
Two ** indicate statistically significant at 10% significance level.
a: Reported estimates of coefficients are multiplied by 10.
b: Adjusted R2 of translog cost function.
c: Adjusted R^2 of share equation of first food group.

Table 5 Estimate of Own and Cross Price Elasticity of Food Group

	Milk	MEB	Grain	FV	FS
Milk	-0.77*	0.05*	0.08*	0.07*	0.57*
	(0.75)[a]	(1.04)	(0.37)	(1.03)	(1.68)
MEB	0.07	-0.59*	0.09*	0.14*	0.28*
	(3.12)	(11.70)	(1.66)	(2.53)	(4.40)
Grain	0.08*	0.09*	-0.48*	0.04*	0.27*
	(0.09)	(0.09)	(0.26)	(0.14)	(0.13)
FV	0.05	0.10*	0.04	-0.40	0.22*
	(3.40)	(2.79)	(3.18)	(15.25)	(5.88)
FS	0.23*	0.09*	0.09*	0.10	-0.51*
	(0.09)	(0.07)	(0.03)	(0.09)	(0.08)

Notes:
One * indicates statistically significant at 5% significance level.
a: Numbers in parentheses are standard deviations.

Table 6 Shadow Price of HEI

Variable	Descriptive	Mean	Std Dev
HEI1	TOTAL FRUIT	0.56[a]	0.70
HEI2	WHOLE FRUIT	0.46	1.74
HEI3	TOTAL VEGETABLES	0.23	0.54
HEI4	DARK GREEN & ORANGE VEG & LEGUMES	0.80	1.29
HEI5	TOTAL GRAINS	-0.32	0.47
HEI6	WHOLE GRAINS	0.33	0.85
HEI7	MILK & MILK PRODUCTS	0.30	0.27
HEI8	MEAT & BEANS	-0.04	0.16
HEI9	OILS	0.16	0.36
HEI10	SATURATED FAT	0.06	0.19
HEI11	SODIUM	0.18	0.39
HEI12	CALORIES FROM SOLID FAT, ALCOHOL & ADDED SUGAR (SoFAAS)	-0.15	0.38
Total		2.56[b]	2.19

Notes:

All the shadow prices are statistically significant at 5% significance level.

a: Mean shadow price of all respondents.

b: Mean of the sum of shadow prices of 12 HEI index.

Table 7 Estimate of Demand for Diet Quality

	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12
Constant	5.10*	4.53*	4.60*	3.39*	5.84*	2.70*	6.78*	9.87*	6.76*	10.43*	5.33*	18.35*
π1[a]	-1.77*	-1.02*	0.23*	0.05**	-0.07*	-0.05**	-0.13*	-0.08*	0.19*	-0.40*	-0.15*	-1.42*
π2	-0.40*	-0.77*	-0.04*	-0.04*	-0.08*	-0.13*	-0.01	-0.03*	0.03	-0.30*	-0.04*	-0.70*
π3	0.06	0.00	-1.47*	-0.53*	0.05*	0.06**	0.20*	-0.14*	0.08	0.63*	0.55*	-0.83*
π4	-0.13*	-0.06*	-0.32*	-0.86*	-0.04*	-0.10*	0.17*	-0.19*	-0.04	-0.09*	0.13*	-0.77*
π5	0.23*	0.25*	0.03	0.13*	-1.12*	-0.45*	0.62*	-0.30*	0.25*	0.54*	0.78*	-2.16*
π6	0.10*	0.05*	0.09*	0.02	-0.16*	-0.97*	0.09**	0.14*	0.28*	-0.15*	-0.03	0.33*
π7	0.13**	0.17*	-0.18*	0.09	-0.22*	-0.22*	-3.18*	-0.24*	0.47*	0.04	1.06*	-3.83*
π8	-0.53*	-0.65*	-0.48*	-0.47*	-0.03	-0.80*	-1.62*	-5.54*	-1.93*	0.86*	0.40*	-7.01*
π9	-0.16*	-0.05	-0.05	-0.05	-0.05	-0.05	0.59*	-0.54*	-4.19*	0.34*	0.22*	-1.35*
π10	-0.30*	-0.08	0.11	0.10	0.01	-0.04	1.76*	-0.96*	0.96*	-4.34*	0.13	-4.34*
π11	-0.48*	-0.26*	0.28*	0.10*	0.09*	0.12*	0.28*	-0.13*	-0.31*	-1.16*	-4.16*	0.52*
π12	-0.08	-0.04	0.20*	-0.08	-0.15*	0.46*	-0.01	-0.42*	0.47*	-0.30*	-0.24*	1.69*
C	0.00	0.00	0.01	0.01	-0.05*	-0.04*	0.10*	0.01	0.10*	-0.13*	0.06*	-0.25*
C^2	0.00	0.00	0.00	0.00	0.00*	0.00*	0.00**	0.00	0.00*	0.00*	0.00	0.01*
Age[b]	0.01*	0.01*	0.01*	0.01*	0.00**	0.01*	-0.01*	0.00	0.01*	-0.01*	0.00	0.02*
Male	-0.28*	-0.19*	-0.21*	-0.21*	0.00	-0.07*	-0.52*	0.34*	-0.36*	0.02	-0.08	-0.64*
Eth1	-0.26*	-0.17	-0.10	-0.20**	-0.02	0.10	0.71*	-0.58*	0.60*	-1.25*	-0.44*	-1.59*
Eth2	-0.13	-0.22**	-0.12	0.02	-0.25*	0.03	-0.52**	-0.06	0.68*	-0.78*	-0.14	-1.81*
Eth3	-0.04	0.03	0.05	0.06	0.07	-0.01	0.25	-0.41*	-0.02	-0.46	-0.04	-1.00*
Eth4	-0.10	-0.16	0.26**	-0.08	-0.07	0.22	-0.42	-0.24	0.65**	0.56	-0.40	0.61
Marriage1	0.08	0.06	0.08	-0.04	0.01	-0.04	-0.08	0.17	-0.30**	0.16	0.10	0.08
Marriage2	0.12	0.21**	0.01	-0.05	-0.03	-0.03	0.22	0.09	-0.78*	0.04	0.10	0.00
Marriage3	0.02	0.00	-0.12	-0.19*	-0.05	0.02	0.02	0.18	-0.43*	0.05	-0.04	-0.03
Marriage4	0.15	0.09	-0.18	-0.28*	-0.11	-0.05	0.41	-0.20	-0.50**	0.55	0.13	-0.24
Marriage5	0.21*	0.16**	0.13	0.11	-0.06	0.14**	0.09	-0.01	-0.08	0.31	0.29**	0.39

PIR	0.00	-0.01	0.02	0.01	-0.01	0.01	-0.01	0.04*	0.01	0.01	-0.03	0.00
Edu1	-0.39*	-0.40*	-0.22*	-0.31*	0.03	-0.23*	-0.21	0.27*	-0.60*	-0.19	0.11	-1.30*
Edu2	-0.36*	-0.34*	-0.18*	-0.38*	-0.02	-0.22*	-0.25	0.26*	-0.43*	-0.72*	0.01	-1.95*
Edu3	-0.28*	-0.21*	-0.21*	-0.36*	-0.06**	-0.18*	-0.12	0.21*	-0.15	-0.87*	0.09	-1.77*
Edu4	-0.21*	-0.20*	-0.16*	-0.21*	-0.03	-0.11*	-0.10	0.20*	-0.05	-0.65*	0.03	-1.48*
N						3639						
Adjusted R^2	0.63	0.70	0.43	0.57	0.45	0.48	0.25	0.37	0.41	0.24	0.49	0.44

Notes:
One * indicates statistically significant at 5% significance level.
Two ** indicate statistically significant at 10% significance level.
a: Shadow price of HEIj, j=1 to 12.
b: Demographic variables are corresponding to those in table 1.

Table 8 Own and Cross Price Elasticity and Expenditure Elasticity of Demand for Diet Quality

	HEI1	HEI2	HEI3	HEI4	HEI5	HEI6	HEI7	HEI8	HEI9	HEI10	HEI11	HEI12	EY
HEI1	-0.71[a]	-0.20	0.01	-0.04	-0.02	0.01	0.01	0.01	-0.01	0.00	-0.04	0.00	0.12
	(1.17)[b]	(0.44)	(0.03)	(0.08)	(0.04)	(0.04)	(0.02)	(0.06)	(0.02)	(0.02)	(0.10)	(0.00)	(0.10)
HEI2	-0.36	-0.68	0.01	-0.02	-0.04	0.01	0.02	0.02	0.00	0.00	-0.02	0.00	0.09
	(0.68)	(1.35)	(0.02)	(0.04)	(0.07)	(0.02)	(0.03)	(0.07)	(0.00)	(0.00)	(0.06)	(0.00)	(0.08)
HEI3	0.05	-0.01	-0.20	-0.08	0.00	0.01	-0.01	0.00	0.00	0.00	0.02	-0.01	0.04
	(0.07)	(0.03)	(0.66)	(0.13)	(0.00)	(0.02)	(0.01)	(0.03)	(0.00)	(0.01)	(0.04)	(0.03)	(0.03)
HEI4	0.03	-0.02	-0.07	-0.88	-0.03	0.00	0.03	0.01	0.00	0.01	0.01	0.01	0.11
	(0.05)	(0.06)	(0.29)	(1.22)	(0.04)	(0.01)	(0.04)	(0.08)	(0.00)	(0.02)	(0.03)	(0.03)	(0.07)
HEI5	-0.01	-0.01	0.00	-0.01	0.06	-0.01	-0.02	0.00	0.00	0.00	0.00	0.00	-0.06
	(0.02)	(0.03)	(0.01)	(0.01)	(0.25)	(0.03)	(0.02)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.02)
HEI6	-0.02	-0.06	0.01	-0.06	0.12	-0.45	-0.06	0.01	0.00	0.00	0.02	-0.07	-0.08
	(0.03)	(0.21)	(0.02)	(0.11)	(0.21)	(0.85)	(0.07)	(0.10)	(0.01)	(0.00)	(0.04)	(0.19)	(0.08)
HEI7	-0.02	0.00	0.02	0.04	-0.04	0.01	-0.39	0.01	0.02	0.02	0.01	0.01	0.13
	(0.03)	(0.02)	(0.05)	(0.08)	(0.07)	(0.03)	(0.70)	(0.09)	(0.06)	(0.08)	(0.02)	(0.02)	(0.10)
HEI8	-0.01	0.00	-0.01	-0.03	0.01	0.01	0.00	-0.01[c]	-0.01	-0.01	0.00	0.01	-0.02
	(0.02)	(0.01)	(0.02)	(0.04)	(0.02)	(0.02)	(0.00)	(0.48)	(0.03)	(0.03)	(0.00)	(0.03)	(0.01)
HEI9	0.02	0.00	0.00	-0.01	-0.02	0.01	0.04	0.02	-0.37	0.01	-0.01	-0.02	0.10
	(0.04)	(0.01)	(0.00)	(0.02)	(0.03)	(0.06)	(0.05)	(0.12)	(1.30)	(0.05)	(0.03)	(0.07)	(0.09)
HEI10	-0.06	-0.06	0.02	-0.04	-0.06	-0.02	0.02	-0.01	0.02	-0.18	-0.08	0.01	-0.11
	(0.14)	(0.28)	(0.12)	(0.09)	(0.14)	(0.08)	(0.04)	(0.07)	(0.09)	(0.90)	(0.25)	(0.05)	(0.15)
HEI11	-0.03	-0.01	0.06	0.04	-0.09	-0.01	0.10	-0.01	0.02	0.00	-0.81	0.01	0.14
	(0.05)	(0.04)	(0.15)	(0.10)	(0.16)	(0.02)	(0.14)	(0.02)	(0.05)	(0.01)	(1.81)	(0.04)	(0.13)
HEI12	-0.21	-0.14	-0.06	-0.18	0.07	0.00[d]	-0.31	-0.03	-0.06	-0.07	0.02	-0.20	-0.10
	(0.56)	(0.57)	(0.26)	(0.52)	(0.67)	(0.06)	(0.73)	(0.51)	(0.21)	(0.42)	(0.07)	(0.79)	(0.54)

Notes:

All the elasticities are statistically significant at 5% significance level, except for c and d.

a: Mean of calculated elasticities of all individuals in the sample.

b: Numbers in parentheses are standard deviations.

[i] There are 6,940 food codes in FNDDS, representing foods that are usually consumed by the U.S. consumers. The CNPP Food Prices Database contains food prices of 4,600 foods in an “as consumed form”. In the 2003-2004 NHNES survey, the number of food consumer by respondents is 4,573. Therefore, the 4,600 foods in CNPP Food Price Database cover most of the foods reported by respondents in NHNES survey.

[ii] Another ways to avoid the problem of zero output levels in estimating translog function is to substitute zero by some arbitrary small number (Cowing, T. G., and A. G. Holtmann. 1983. "Multiproduct Short-Run Hospital Cost Functions: Empirical Evidence and Policy Implications from Cross-Section Data." *Southern Economic Journal* 49:(3): 637-653.), or used Box-Cox transformation of the original output variables (Caves, D. W., L. R. Christensen, and J. A. Swanson. 1980. "Productivity in U.S. Railroads, 1951-1974." *The Bell Journal of Economics* 11:(1): 166-181.). The first approach was attempted in our analysis but the arbitrarily chosen small number had great impacts on the final results. The second approach was also attempted, but the estimated lamda coefficients for some HEI index were negative, which also prevented us to transform the zero HEI scores. Adding one to the original HEI index seems like a better solution because the HEI index is just an instrument to measure diet quality, not the true nutrient intakes from household production. Adding one to the original HEI index simply scaled the total HEI score from 0 to 100 to 12 to 112.

[iii] If all explanatory variables are the same for all equations, SUR estimates are the same as OLS estimates.

[iv] Sometimes people uses 1.85, which is the criterion required for WIC program.