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

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Abstract

A large volume of literature has been focusing on the measure of diet quality and consumer demand for food. However, little has estimated consumer demand for diet quality. In this article, we systematically estimate consumer demand for diet quality using the healthy eating index (HEI) developed by the U.S. Department of Agriculture. The Results show that consumers have insufficient consumption of the food containing dark green, orange vegetable, legumes and total grain. Age and education have significant impact on consumer demand for diet quality but income does not. The own price elasticities of demand for diet quality are inelastic and are larger than cross price elasticities. Asymmetric cross price elasticity exists between the diet quality of solid fats, alcoholic beverages and added sugars and the quality of other diet groups. This information is critical in policies and programs that are designed to improve consumer healthy food choice which can reduce social cost of public health.

Key words: Healthy Eating Index, Diet quality, Demand, Household production, Translog cost function

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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 (Aldana et al., 2005; Allen, 2006; Bertsias et al., 2005; Browe et al., 1966; Park et al., 2009b). The U.S. Department of Agriculture (USDA) published new food guidelines in 2005 - "MyPyramid" - to help consumers make healthy food choices. Based on the Dietary Guidelines 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 studies has focused on determining the nutrient and dietary intakes among different groups and the impact of diet on consumer health (Beydoun and Wang, 2009; Eastwood et al., 1984; Park et al., 2009a; Vining, 2008); on evaluating the dietary quality using certain type of indexes such as the HEI (Angelopoulos et al., 2009; Breslow et al., 2006; O'Neil et al., 2010; Schmidt et al., 2005); and on determining the relationship between diet cost and quality (Drewnowski and Darmon, 2005; Lo et al., 2009). Economic studies have extensively focused on consumer demand for food products such as fruits and vegetables (Heien and Wessells, 1990; Pollack, 2001; Price and Mittelhammer, 1979), meats (Chavas, 1983; Haley, 2001) and beverage (Brown et al., 1994; Heien and Pompelli, 1989), and other food products. It seems there is a gap between nutritional studies on diet and economic analysis of demand for a healthy diet (diet quality). For instance, some demand studies related to diet quality use food diversity as proxy of diet quality (Lee, 1987; Shonkwiler et al., 1987; Thiele and Weiss, 2003). Although food diversity has been shown to be related to diet quality (Krebs-Smith et al., 1987; Randall et al., 1985; Ruel, 2003), it may not be as good as the HEI that is developed at the base of dietary guidelines. Other studies investigated the connection between cost and diet quality (Cade et al., 1999; Duffey et al., 2010; Lo et al., 2009); however, some of those studies only include a limited number of food products in their cost calculations. Because the price of diet quality is not calculated, the demand for diet quality is never studied. Estimating consumer's demand for diet quality is important for policies or programs that are designed for improving healthy food choices. For instance, how a tax on sugar-sweetened beverage affects the diet quality of different diet groups, will a tax or a subsidy be a more efficient tool to improve healthy food choice, or to what extend will a program such as Food Stamps help improve participants' diet quality.

The fact that there are few studies addressing consumer demand for diet quality is likely the results of the lack of a good measure of healthy status of a diet and the unavailability of the food prices corresponding to numerous food items in consumer's diets. The HEI that measures the healthy status of a diet was initially developed in 1995, and a new index based on 2005 Dietary Guidelines for Americans was developed in 2006. However, the unavailability of food prices that match the food products used in calculating the HEI still creates barriers to estimate consumer demand for a healthy diet. In 2009, the Center for Nutrition Policy and Promotion (CNPP) published the Food Price Database of 4,600 food products in "as consumed" forms for 2003-2004 (USDA-CNPP, 2009). The food products in the database match those reported by respondents in Dietary Interview-Individual Foods (DIIF) and Dietary Interview-Total Nutrient Intakes (DITN) of National Health and Nutrition Examination Survey (NHANES, CDC, 2007). This enables us to estimate the cost of accessing a food product in different food groups and consumer demand for diet quality as well. In this article, we use household production theory to develop a theoretical framework to study consumer demand for diet quality. We also demonstrate a way to empirically estimate the diet cost function by imposing some theoretical properties, which is essential for obtaining proper demand elasticities. Unlike most of the current studies, we empirically estimate consumer demand for diet quality of the twelve diet groups that consist of total diet. Compared to previous research mainly focusing on the overall diet quality, the segregated estimation of the demand may provide more useful information for the development of policy instruments to promote healthy food choice. We expect the results in this paper can 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.

This article is organized as follows. We first present the concept and the method of calculating the HEI; second, we demonstrate a model that can be used to model consumer demand for diet quality based on the way that the HEI is calculated; third, we explain the data sources, followed by empirical analysis; finally we give the results and conclusions.

The Healthy Eating Index

The HEI is developed to evaluate the diet quality of individuals at the age of 2 years or 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 intakes are calculated 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 of 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 the 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 intake of each group is compared with the corresponding recommended intake of that group. If the nutrient intake from a diet group, say Total Fruit meets the recommended quantity, it will receive the maximum HEI score for that group. If the nutrient intake for 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 will be given 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 (the 10th diet group) is less than or equal to 7% of the total energy from the food consumption, the Saturated Fat diet group receives the highest HEI score. If the energy from SoFAAS (the 12th diet group) is less than or equal to 20% of the total energy, the SoFAAS diet group gets the maximum HEI score (for more details, see Guenther et al., 2007; Patricia et al., 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 HEI scores and can be used to assess the overall diet quality for food consumption of an individual. A higher HEI score indicates better diet quality. The HEI has been used to evaluate diet quality among various consumer groups (Angelopoulos et al., 2009; O'Neil et al., 2010; Pick et al., 2005). Some studies found a negative relationship between the HEI and some healthy problems, implying the effectiveness of using the HEI to assess diet quality (Ford et al., 2005; Guo et al., 2004; Kennedy et al., 2001; Reedy et al., 2008; Weinstein et al., 2004).

Economic Model

According to the household production theory (Deaton and Muellbauer, 1984), households choose 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 food products 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 can 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) $C=C(p, z)$

which 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 the HEI, the household production function can be defined as:

$$B \mid q = t \quad \text{and } z=f(t^*),$$

where

B= m by n matrix that defines the transformation from food consumptions to nutrient intakes,

q= a column vector (n by 1) of food consumption

t_i =nutrient intake of diet groups, for i=1,…,12,

t_{13}=total calories from food consumption,

$t_i^*=1000*t_i/t_{13}$, for i=1-9, and 11.

Based on the amount of nutrient intakes, the diet quality *z* is obtained by a set of functions *f* that defines the relationship between nutrient intakes and diet qualities. Because of the linear relationship between food consumption and nutrient intake, the nutrient intake is a non-decreasing function of cost. However, this is not true for diet quality *z* - diet quality is based on the relative intake of nutrient rather than the absolute amount of nutrient intake. For instance, 10 of 12 HEI's are based on the nutrient intakes per 1,000 calories. In addition, the intakes of Saturated Fat, Sodium and SoFAAS have negative relationships with diet quality, because of the health risks related to the excessive intake of those diet groups. The nonlinear or sometime negative correlation between nutrient intake and diet quality leads to the result that 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 et al., 1995).

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

(3) $\pi_i = \partial C/\partial z_i,\ i=1,\ldots, 12.$

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

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

where *u* is a 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 estimators of shadow price π and expenditure C^0, the demand for, as well as the price elasticities of demand for diet quality can be obtained by estimating the demand system specified in equation (5).

The Data

The 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 food 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 information for each food listed in USDA food codes. The nutrient information helps transform individual food intake to nutrient intake. The total calorie intake from food consumption from DITN is used to transform the nutrient intake from absolute amount into intake per 1,000 calories. The MyPyramid Equivalents Database (Bowman et al., 2008) is used to transform individual food and nutrient intakes into cup or ounce equivalents of diet groups corresponding to those in Dietary Guidelines for Americans, 2005, which helps calculate the HEIs of different diet groups. In addition, the foods listed in 2003-2004 CNPP Food Prices Database[i] matches with the food products 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 food products 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, used as prices of food paid by individuals. The five marketable food groups include Fruits and Vegetables (FV, aggregation of fruits group and vegetables group), Fats and Sugars (FS, aggregation of fats, oils, and salad dressing group and sugars, sweets and beverages group), Meat, Eggs and Beans[ii] (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 (or 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 HEIs that measures diet quality.

Empirical Analysis

For respondents of ages equal or greater than 20 years in the NHANES, the HEI scores are calculated based on the average food consumptions in two days. Respondents younger than 20 years were removed from the analysis according to the fact that most individuals of age 20 years or older will make their own food choice decisions, thus reflecting the demands for healthy diet quality 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 et al., 1980; Cowing and Holtmann, 1983; Shonkwiler et al., 1987). The translog cost function is specified as:

(6)

$$lnC = \alpha_{\mathbf{0}} + \sum_{i}^{n} \alpha_i lnp_i + \sum_{j}^{m} \beta_j lnz_j + 0.5 \sum_{i}^{n}\sum_{j}^{n} \alpha_{ij} lnp_i lnp_j + 0.5 \sum_{i}^{m}\sum_{j}^{m} g_{ij}\, lnz_i\, lnz_j + \sum_{i}^{n}\sum_{j}^{m} \gamma_{ij}\, lnp_i\, l$$

where *C* is the individual average expenditure on foods in two days; *p* is the price of marketable foods; *z* is HEI measuring the diet quality; n=5 for the five marketable food groups; and 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[iii]. This shifts the minimum score of HEI from zero to 1, but is still consistent with the original HEI. Theoretical restrictions such as homogeneity ($\sum_{i}^{n} \alpha_{ij} = \mathbf{0}$, $\sum_{i}^{n} \alpha_i = \mathbf{1}$, $\sum_{i}^{n}\sum_{j}^{m} \gamma_{ij} = \mathbf{0}$), 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 the other hand, will lead to the cost function being "too negative semidefinite", thus result in an upwardly biased estimation of cross price elasticities (Diewert and Wales, 1987,p48). Ryan 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 Ryan and Wales approach because of the concern with the biased estimation of substitution effects between inputs that may result from imposing the globally concavity. To impose 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) ,

where U is a triangular matrix, α_i is the parameter defined in equation (6) and $\delta_{ij} = \mathbf{1}$ if i=j and 0 otherwise. 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:

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

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 , and $\varepsilon_{ij} = \frac{\alpha_{ij}}{w_i} + w_j$, respectively. The shadow price of the diet quality z_j, or HEI is estimated as

(9)

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

$$z_j = \theta_{\mathbf{0}} + \sum_i^m \theta_i \pi_i + \lambda_{\mathbf{1}} C + \lambda_{\mathbf{2}} C^{\mathbf{2}} + \sum_i^k \omega_i D_i, j = 1, \dots, m\,. \tag{10}$$

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. Despite the fact that the shadow prices in the demand equations may be endogenous, we used ordinary least square (OLS) methods to estimate the system equations of demand for diet quality[iv]. This is a plausible solution due to two facts. First, very limited information is available to be used as instrumental variables in current cross-section data, and weak instruments may result in worse estimation than simple OLS methods (Bound et al., 1995; Stock et al., 2002). In addition, as pointed out by Deaton and Muellbauer

(1984), "given the two-stage procedure, we can take" equation (10) "as behavioral equations, albeit one linking endogenous variables to both exogenous and other endogenous variable" (Deaton and Muellbauer, 1984,p248).

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, and the mean value of Poverty Index Ratio (PIR) is 2.62. The PIR is the ratio of income to the household poverty threshold based on the household size. Because the poverty threshold is calculated according to the household size, the PIR variable contains information on both household income and household size. PIR ranges from 0 to 4.99 and capped 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[v]. 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 FS is the highest, about 1.9 kilogram (kg)/day (figure 1). The consumption of MILK, MEB, GRAIN, and FV 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 is the lowest, about $0.47 per day, followed by the spending on FS ($0.57). Consumers spend their most money on MEB ($1.47), followed by grain products ($0.94), and FS ($0.86). Because of the large quantity and low expenditure on FS, the average price of FS is the lowest, about $0.37/kg. MEB has the highest price of $2.92/kg, followed by GRAIN ($1.60/kg), MILK ($1.41/kg) and FV ($1.29/kg).

The average total HEI score is 56.21. The SoFAAS diet group receives the highest score of 10.46 and the whole grain diet group receives the lowest score of 1.17 (table 2). However, because the maximum HEI scores of different diet groups are different, the relative score calculated as the ratio between HEI score and the maximum score that can be obtained by a corresponding diet group will provide more information on the diet quality. The ratio between the mean HEI score and the maximum score for Whole Grains is the lowest, about 0.23. It implies that on average the consumption of whole grain is about 77% lower than the maximum level that is defined by the 2005 Dietary Guidelines 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 closest to the maximum 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 over consumption of sodium among respondents.

Estimates of Cost and Share Equations

Following Ryan 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 1,485 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 satisfies 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 3 reports the estimates of the parameters for the translog cost function and the share equations. The estimates of the parameters of food prices ($\alpha_i, i = 1 \ldots 4$) are all significant at 5% significance level, and most parameters of the interactions of food prices and HEIs ($\gamma_{ij}, i = 1 \ldots 4, j = 1 \ldots 12$) are significant at 5% significance level. None of the estimates of the parameters of HEIs ($\beta_i, i = 1 \ldots 12$) are significant, and only a few estimates of the parameters of interaction between HEIs ($g_{ij}, i = 1 \ldots 12, j = 1 \ldots 12$) 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 Total Fruit increase by one percent, the budget share of food group MILK 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 groups will result in increasing expenditure on food products containing high level nutrients for that diet group, thus reduce the spending on other food groups. Results also show that estimates of $\gamma_{i12}, \ i = 1 \ldots 4$ 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 might be explained by the fact that improving diet quality in SoFAAS requires less intake of calories from SoFAAS.

The price elasticities of demand for food groups shown in table 4 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 arrre 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 food products. 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 estimate of parameters of MILK has the largest magnitude, which means that policies such as a tax or a subsidy on a diary product may have a largest economic impact on the consumption of milk and milk products. In addition, the cross-price elasticities of FS with respect to Milk, MEB, GRAIN and FV have larger magnitudes compared to the cross-price elasticities between Milk, MEB, GRAIN and FV. This implies that policy instruments on FS rather than on other foods may have larger impacts on structure change of food consumption in order to promote health food consumption.

Demand for a Healthy Diet

The shadow prices for each HEI are calculated for every respondent in the sample using equation (9). Table 5 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 in 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 et al., 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 consumers are not willing to pay for an improvement of diet quality of those three diet groups or simply means that an increases 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 6. 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 the shadow prices of HEI overall significantly affect consumer demand for diet quality. The only two exceptions are shadow prices of HEI9 and HEI10. The shadow prices of diet quality of Oil (HEI9) and diet quality of Saturated Fat (HEI10) 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 and Saturated Fat. The expenditure on food consumption, significantly affects the demand for diet quality of all groups. Increasing food expenditure significantly improves the diet quality of Total Fruit (HEI1), Whole Fruit (HEI2), Total Vegetable (HEI3), Dark Green & Orange Veg & Legumes (HEI4), Milk & Milk Products (HEI7), Oils (HEI9) and Sodium (HEI11); however, at the same time decreases the diet quality of Total Grain (HEI5), Whole Grain (HEI6), Meat and Beans (HEI8), Saturated Fat (HEI10) as well as SoFAAS (HEI12). The quadratic relationship between food expenditure and diet quality may exist, however, although significant, all the estimates of expenditure squares are close to zero.

Age, though with small scale, significantly affect consumer demand for diet quality, and for most diet group, 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 containing dairy products by older people may be a result of concern with fat in milk and milk products. However, by avoiding the fat in the milk and milk product, older people obtains too much calories from other food sources that are high in saturated fat. Overall, the demand 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 energy from the consumption of meat than from other food products. The estimates of Eth1 (Non-Hispanic White) of eight equations (HEI1- HEI4, HEI8, HEI10-HEI12) are statistically 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's demand for diet quality of Milk and Oils is significantly higher than the base group. 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 are not statistically significant, which means that poverty level or household income does not have a significant impact on consumer demand for diet quality. This result is different from Mancino, Lin, and Ballenger (2004) and other researchers (Darmon and Drewnowski, 2008) who found that income had positive relationship with diet quality. Mancino, Lin and Ballenger used total HEI score to measure the overall diet quality of consumer food consumption and Darmon and Drewnowski used dietary energy density as the index of overall diet quality. In this study, we investigate the impacts of income on each of the twelve diet groups. In addition, most studies that demonstrate a positive relationship between diet quality and income do not control for the price effect on diet group– high income people exhibit higher diet quality is because they can afford the food products that are healthier and more expensive. However, with the shadow prices (which are different from food prices) of diet quality being equal, high income people may not demand more for diet quality than low income people. Particularly in a developed country such as the U.S., Engel index is very low and income might not so important any more. Consistent with the previous studies, we find that education has an influential impact on the demand for diet quality. Compared to people with College Graduate or Above degree, consumers will less advance degree 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 7. Most of the elasticities are statistically significant at 5% significance level except for 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 are relatively larger and are negative. This means that a change in the price of diet quality of other diet groups will have large impacts 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 a change in the price of diet quality of SoFAAS does not have a 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 target on the price changes of HEI12 may be effective in deceasing calories from SoFAAS while at the same time, improving the diet quality of other diet groups or keeping them unchanged.

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, the diet qualities of Total Grain, Whole Grain, Meat & Bean decrease, however, the diet qualities of Saturate Fat and SoFAAS increase. This result also reflects the qualities of fruit, vegetable, milk and milk products, and oils are positive related to expenditure.

Conclusion

Promoting health diet has been one of the first priorities of many countries. USDA has continuously been working on providing scientific information on the healthy food consumption using various programs such as MyPyramid. The HEI developed according to 2005 Dietary Guidelines for Americans, enable us to have an accurate measure of an individual's diet quality. The HEI, though has been used to investigate diet quality for different populations, has not be employed to study consumer demand for quality of diet. In this paper, we make use the newly published price data by the CNPP, and based on the household production theory to 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 Dark Green & Orange Veg & Legumes in the diet may be the biggest problem facing the U.S. consumers. Consumers are most likely to pay a 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. However, because the shadow prices of diet quality equal marginal costs, consumers may improve their diet quality of these three diet groups without extra food expenditures. 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. The fact that income does not have a significant impact on consumer demands for diet quality simply implies that with marginal cost of diet quality being controlled, lower income consumers demand equally for diet quality as high income consumers. 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 significant impact of education on consumer demand for diet quality further reflects the importance of some of the nutritional education campaign that aims to help consumers to be aware of and understand the healthy benefits of foods (Kelder et al., 1995; Perez-Escamilla et al., 2008; Vijayapushpam et al., 2010).

The results of this study may provide critical and valuable information for policy makers and stakeholder that are targeting on the improvement of the diet qualities. It can be further extended to study the linkage between the demands for diet quality and individual health problems such as obesities. More food price information based on different regions will enable us to investigate the regional differences in consumer's demand for diet quality.

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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 HEI Score of Total and Individual Diet Group

Variable	Description	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 3 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 4 Estimates of Own and Cross Price Elasticity of Demand for Foods

	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 5 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	-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 6 Estimate of Demand for Diet Quality

	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12
Constant	4.82*	4.26*	4.47*	3.28*	5.83*	2.67*	6.86*	10.11*	6.61*	10.29*	5.19*	17.94*
π1[a]	-1.87*	-1.06*	0.34*	0.11*	-0.10*	-0.04	-0.13**	-0.17*	0.22*	-0.42*	-0.16*	-1.54*
π2	-0.45*	-0.90*	-0.05*	-0.05*	-0.09*	-0.16*	-0.04	-0.04*	0.03	-0.36*	-0.06*	-0.86*
π3	0.10*	0.05	-1.79*	-0.62*	0.06*	0.05	0.37*	-0.25*	0.00	0.55*	0.69*	-1.32*
π4	-0.12*	-0.04*	-0.37*	-1.04*	-0.05*	-0.12*	0.23*	-0.28*	-0.06**	-0.14*	0.16*	-0.97*
π5	0.15*	0.21*	-0.01	0.13*	-1.26*	-0.53*	0.48*	-0.26*	0.27*	0.58*	0.80*	-2.69*
π6	0.09*	0.05**	0.07*	0.01	-0.18*	-1.15*	0.10**	0.19*	0.30*	-0.21*	-0.05	0.26*
π7	0.12	0.16**	-0.10	0.17*	-0.29*	-0.29*	-4.55*	-0.04	0.74*	0.31	1.09*	-4.51*
π8	-0.69*	-0.80*	-0.52*	-0.66*	0.10	-0.83*	-1.90*	-6.97*	-2.36*	0.99*	0.40**	-7.88*
π9	-0.10	0.03	-0.02	-0.01	-0.07**	-0.03	0.72*	-0.64*	-4.90*	0.52*	0.29*	-1.56*
π10	-0.20**	0.01	0.12	0.14	0.04	-0.03	2.12*	-1.25*	1.27*	-5.05*	0.16	-5.21*
π11	-0.52*	-0.28*	0.37*	0.12*	0.11*	0.14*	0.21**	-0.10	-0.31*	-1.31*	-4.86*	0.82*
π12	0.00	0.00	0.22*	-0.10	-0.14*	0.55*	-0.15	-0.47*	0.61*	-0.29**	-0.34*	2.20*
C	0.05*	0.04*	0.03*	0.03*	-0.05*	-0.03*	0.11*	-0.03*	0.11*	-0.12*	0.08*	-0.23*
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	-0.34*	-0.23*	-0.23*	-0.23*	0.01	-0.09*	-0.52*	0.41*	-0.36*	-0.02	-0.11	-0.70*
Eth1	-0.32*	-0.21**	-0.17**	-0.25*	-0.03	0.07	0.70*	-0.50*	0.54*	-1.35*	-0.39*	-1.73*
Eth2	-0.14	-0.23**	-0.17	-0.02	-0.25*	0.01	-0.47**	-0.02	0.63*	-0.86*	-0.10	-1.80*
Eth3	-0.03	0.03	-0.01	0.04	0.07	-0.02	0.22	-0.34*	-0.04	-0.50**	0.01	-0.98*
Eth4	-0.08	-0.14	0.19	-0.12	-0.10	0.19	-0.37	-0.22	0.62**	0.48	-0.29	0.59
Marriage1	0.13	0.10	0.08	-0.04	0.01	-0.01	-0.11	0.14	-0.24	0.20	0.08	0.15
Marriage2	0.18	0.26*	0.00	-0.05	-0.02	-0.01	0.18	0.05	-0.73*	0.09	0.10	0.05
Marriage3	0.01	0.00	-0.12	-0.20*	-0.05	0.03	-0.04	0.13	-0.37**	0.05	-0.03	-0.06
Marriage4	0.19	0.11	-0.17	-0.26**	-0.11	-0.03	0.40	-0.25	-0.48	0.55	0.17	-0.23
Marriage5	0.27*	0.19*	0.15**	0.12	-0.07	0.15**	0.02	-0.07	0.00	0.36	0.28**	0.46
PIR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
Edu1	-0.37*	-0.36*	-0.23*	-0.32*	0.04	-0.23*	-0.14	0.17**	-0.59*	-0.18	0.17	-1.24*
Edu2	-0.35*	-0.30*	-0.20*	-0.38*	0.00	-0.23*	-0.26**	0.21*	-0.44*	-0.73*	0.08	-1.93*
Edu3	-0.28*	-0.19*	-0.22*	-0.36*	-0.05	-0.19*	-0.09	0.16*	-0.16	-0.88*	0.13	-1.75*
Edu4	-0.20*	-0.18*	-0.16*	-0.21*	-0.02	-0.11*	-0.10	0.15*	-0.04	-0.66*	0.06	-1.41*
N	3639											
Adjusted	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 7 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.

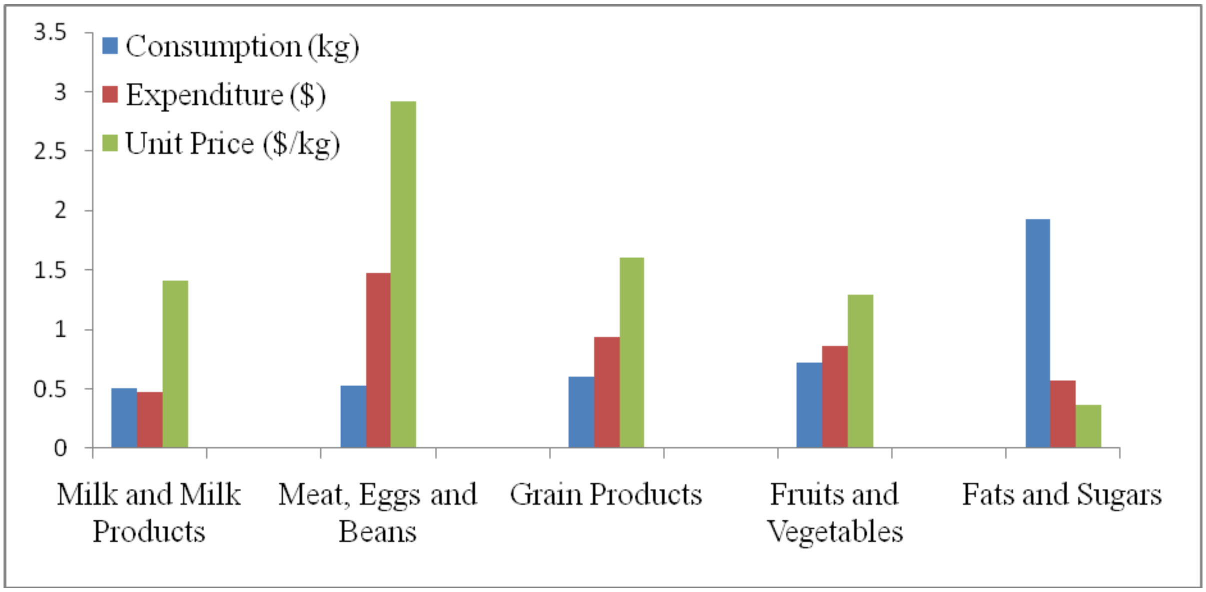

Figure 1 Food Consumption, Expenditure and Price

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[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] The aggregation of food group meats and beans is consistent with the calculation of HEI. In calculating HEI, the consumption of bean is first treated as consumption of meats. Only if the HEI of meats reach the highest score, the rest of consumption of beans can be considered as vegetable consumption.

[iii] Another ways to avoid the problem of zero output levels in estimating translog function is to substitute zero by some arbitrary small number (Cowing TG, Holtmann AG. Multiproduct Short-Run Hospital Cost Functions: Empirical Evidence and Policy Implications from Cross-Section Data. Southern Economic Journal 1983;49; 637-653.), or used Box-Cox transformation of the original output variables (Caves DW, Christensen LR, Swanson JA. Productivity in U.S. Railroads, 1951-1974. The Bell Journal of Economics 1980;11; 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.

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

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