# Nutrient Elasticities in a Complete Food Demand System

**Kuo S. Huang**

This study explores the linkage of the determinants of food choice with consumer nutrient availability by developing a procedure to measure changes in nutrient availability as the demand for food items change. It uses demand elasticities from traditional demand analysis to estimate elasticities of changes in the nutritional content of consumer diets. The procedure is applied to estimate nutrient elasticities for fifteen nutrients in response to changes in thirty-five food prices and per capita income.

*Key words*: complete food demand system, nutrient elasticities.

The issues of health and diet have become a major concern for consumers. Medical evidence links excessive saturated fat and cholesterol in the typical American's diet with heart disease—the leading cause of death in the United States. Also, some women and children in low-income households may have nutritional deficiencies and nutrition-related health problems (Senauer, Asp, and Kinsey, p. 222). In 1990, the U.S. National Nutrition Monitoring and Related Research Act was passed. This act calls for a ten-year comprehensive plan to provide information about the role and status of nutrition factors that contribute to the health of Americans. An interagency board, consisting of representatives from twenty-two federal agencies, coordinates the nutrition monitoring and related research activities.

Given the demand structure for food and the bundle of nutrient attributes each food product contains, it is possible to derive the implied relationship between nutrient availability and changes in food prices and income. Only a few studies have incorporated nutritional factors into food demand analyses. Some use a cholesterol information index by measuring the number of medical journal articles that disseminate cholesterol information as a variable in demand equations (Brown and Schrader, Capps and Schmitz). Some fit demand equations for specific nutrients as functions of income and sociodemographic variables from household survey data (Adrian and Daniel, Devaney and Fraker, Basiotis et al.). Others propose a formula to calculate nutrient elasticities for use in measuring price and income effects on nutrient availability, but provide no information on how to derive the formula from an underlying demand model (Pitt; Sahn; Gould, Cox, and Perali).

Lancaster provides a conceptual framework to link food choice and nutritional status. He views nutrients as attributes or characteristics of food consumption, and consumers attain the nutrient attributes they most desire by maximizing utility as a function of nutrient attributes, as opposed to food quantities in classical demand theory. The consumer choice problem is to maximize the utility function subject to budget constraint and a set of transformation equations that link nutrient availability to food consumption. This approach, however, is rather difficult to implement empirically because a nonlinear programming problem has to be solved to obtain the nutritional implication of food consumption.

A comprehensive framework for studying the effects of economic factors on nutritional status of consumers is not available. The purpose of this study is to link food choice with nutritional status in the context of the classical demand framework. Instead of applying Lancaster's programming approach, this study develops an

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efficient procedure to measure nutrient availability by way of demand elasticities for food items from a traditional demand analysis. In particular, interdependent demand relationships including own- and cross-price and income effects of a complete food demand system are incorporated directly into the measurement of nutrient elasticities. This procedure is applied to a demand system consisting of thirty-five food categories to estimate nutrient elasticities for fifteen nutrients. These results provide useful information for nutrition monitoring and related research activities.

## Conceptual Framework

To measure nutrient elasticities, this study applies the following differential-form demand model extensively used by Huang. Let $p_i$ and $q_i$ denote the $i$th price and associated quantity demanded in the allocation of a representative consumer's income $m$ across a set of $n$ commodities including foods and nonfoods. The demand relationships can be approximated by relating small changes from any given point on the $n$-commodity demand surface as

$$(1) \quad dq_i = \Sigma_j(\partial q_i/\partial p_j)dp_j + (\partial q_i/\partial m)dm.$$

All subscripts of variables and summation throughout this paper refer to $n$ commodities and $\ell$ nutrients as $i, j = 1, 2, \ldots, n$ and $k = 1, 2, \ldots, \ell$.

By further expressing the price and income slopes in terms of elasticities, a differential-form demand model can be obtained as

$$(2) \quad dq_i/q_i = \Sigma_j e_{ij}(dp_j/p_j) + \eta_i(dm/m)$$

where $e_{ij} = (\partial q_i/\partial p_j)(p_j/q_i)$ and $\eta_i = (\partial q_i/\partial m)(m/q_i)$ are, respectively, price and income elasticities. This demand model is a general approximation of conceptual demand relationships. In view of classical demand theory, the elasticities are constrained by symmetry ($e_{ji}/w_i + \eta_j = e_{ij}/w_j + \eta_i$), homogeneity ($\Sigma_j e_{ij} + \eta_i = 0$), and Engel aggregation ($\Sigma_i w_i \eta_i = 1$), where $w_i = p_i q_i/m$ is the $i$th expenditure share. The fixed parameters in the model representing demand elasticities may be too strong an assumption, because restrictions are thereby placed on the implied utility structure. Nevertheless, as shown below, the advantage of using this demand model is that the estimated demand elasticities can be applied directly to the measurement of nutrient elasticities.

To explore the linkage of the demand model to nutrient availability, information about the nutrient values of each food consumed is needed. Let $a_{ki}$ be the amount of the $k$th nutrient obtained from a unit of the $i$th food. The total amount of that nutrient obtained from various foods, say $\phi_k$, may be expressed as

$$(3) \quad \phi_k = \Sigma_i a_{ki} q_i.$$

This is what Lancaster called the "consumption technology" of consumer behavior. The values of $a_{ki}$'s for nonfoods will be assigned to zero; thus the terms associated with nonfoods will disappear. This equation, including all foods consumed, plays a central role in the transformation of food demands into nutrient availability.

By substituting the demand equation (1) for the quantity variable of equation (3), changes in consumer nutrient availability become

$$(4) \quad d\phi_k = \Sigma_i a_{ki}[\Sigma_j(\partial q_i/\partial p_j)dp_j + (\partial q_i/\partial m)dm].$$

Furthermore, the relative changes of consumer nutrient availability can be expressed as functions of the relative changes in food prices and per capita income as follows:

$$(5) \quad \begin{aligned} d\phi_k/\phi_k &= \Sigma_j(\Sigma_i e_{ij} a_{ki} q_i/\phi_k)dp_j/p_j \\ &\quad + (\Sigma_i \eta_i a_{ki} q_i/\phi_k)dm/m \\ &= \Sigma_j \pi_{kj} dp_j/p_j + \rho_k dm/m \end{aligned}$$

where $\pi_{kj} = \Sigma_i e_{ij} a_{ki} q_i/\phi_k$ is a price elasticity measure relating the effect of the $j$th food price on the availability of the $k$th nutrient, and $\rho_k = \Sigma_i \eta_i a_{ki} q_i/\phi_k$ is an income elasticity measure relating the effect of income on the availability of that nutrient.

Obviously, the measurement of $\pi_{kj}$ represents the weighted average of all own- and cross-price elasticities ($e_{ij}$'s) in response to the $j$th price with each weight expressed as the share of each food's contribution to the $k$th nutrient ($a_{ki}q_i/\phi_k$'s). Similarly, the measurement of $\rho_k$ represents the weighted average of all income elasticities ($\eta_i$'s) with each weight again expressed as the share of each food's contribution to the $k$th nutrient. Thus the general calculation of nutrient elasticity matrix, say **N**, for the case of $\ell$ nutrients and $n$ foods can be obtained as a product of multiplying matrix **S** by matrix **D** as follows:

$$(6) \quad \mathbf{N} = \mathbf{S} * \mathbf{D}$$

where **N** is the $\ell \times (n + 1)$ matrix of nutrient elasticities in response to changes of food prices and income, **S** is the $\ell \times n$ matrix with entries of each row indicating a food's share of a particular nutrient, and **D** is the $n \times (n + 1)$ matrix of demand elasticities. From these nutrient elasticity measurements, a change in a particular food price or per capita income will affect all food quantities demanded through the interdependent demand relationships and thus cause the levels of consumer nutrient availability to change simultaneously.

## Empirical Application

The procedure for measuring nutrient elasticities is applied to the U.S. food sector for a total nutrient profile of consumer diets. A total of thirty-five food categories are covered. In addition to food demand elasticities, information about the nutrition attributes of foods and the amount of per capita food consumption are required for calculating nutrient elasticities. Most nutritive values of foods are compiled from Gebhardt and Matthews's *Nutritive Value of Foods*, which gives a detailed account of nutritive values for household measures of commonly used foods. The nutrition attributes of beef, pork, chicken, and turkey are obtained from the U.S. Department of Agriculture (USDA), Agricultural Handbooks Nos. 8-5, 8-10, and 8-13. These handbooks provide additional nutritive values of meat carcasses, which contain more adequate nutrition information for the U.S. disappearance data for meat quantities used in this study.

The nutrition values of food per pound for fifteen selected nutrients are compiled in table 1. Food energy is measured in food calories (kcal); protein, fat, and carbohydrate in grams; vitamin A in retinol equivalent (re); and all other nutrients in milligrams. Each food category of cheese, flour, rice, fats and oils, peanuts and nuts, and sugar provides relatively higher food energy (above 1,500 kcal) than other foods. These food energy contents are closely related to three energy-yielding nutrients: protein, fat, and carbohydrate. Cheese, peanuts, and nuts have high levels of protein and fat. Butter, margarine, and cooking oils are mostly fats, while flour, rice, and sugar are mainly carbohydrates. The cholesterol levels are highest for eggs (1,932 mg) and butter (991 mg). Carrots are exceptionally rich in vitamin A (12,758 re). Fruits and vegetables are a major source of vitamin C, especially oranges (242.4 mg) and grapefruits (155 mg).

In addition to the unit nutritive value of food, the amount of food consumed is another factor determining the level of nutrients available to consumers. Averages of food consumptions over 1989–93 (listed in the last column of table 1) are compiled from Putnam and Allshouse's *Food Consumption, Prices, and Expenditures*. The consumption of chicken (73.4 lb) is more than beef (68 lb) and pork (51 lb). Staple foods such as milk (220 lb) and flour (150 lb) are consumed heavily. By multiplying the amount of each food consumption by its unit nutritive values, total nutrients available to consumers and food shares of nutrients are obtained, as presented in table 2. This set of nutrient information depicts the source of nutrients and provides a basis [the **S** matrix in equation (6)] for measuring nutrient elasticities.

In table 2, combined flour and rice consumption is a major source of energy (24.97%), protein (19.77%), carbohydrate (48.85%), phosphorus (11.88%), iron (57.86%), thiamin (57.66%), riboflavin (29.92%), and niacin (43.87%). The significant nutrients in flour and rice are consistent with USDA's suggested daily food choices in *The Food Guide Pyramid*—six to eleven servings of bread, cereals, rice, and pasta, and two to five servings for each of the other four food groups: (*a*) vegetables; (*b*) fruits; (*c*) meat, poultry, fish, dry beans, eggs, and nuts; and (*d*) milk, yogurt, and cheese. Other major sources of protein are beef (13.02%), pork (7.99%), chicken (12.74%), and milk (9.89%). As expected, the consumption of eggs gives the highest level of cholesterol by 38%, while beef, pork, and chicken each contribute about 10% of cholesterol. Cheese, milk, and evaporated and dry milk are major sources of calcium, phosphorus, potassium, sodium, and vitamin A. Carrots provide about 23% of vitamin A. Oranges and orange juice, are the major source of vitamin C, providing 11% and 34%, respectively.

Food demand elasticities are another important component [the **D** matrix in equation (6)] in computing nutrient elasticities. For purposes of this study, a portion of the complete food demand system reported in Huang is used. Some minor "other" food categories and a nonfood sector in Huang's demand system are excluded from nutritional analysis because of either difficulty or irrelevance in defining nutritive value. Huang's demand system was specified as in equation (2) and estimated using annual data from 1953 to 1990. Constrained maximum likelihood is used for demand system estimation, with the parametric constraints of homogeneity,

**Table 1. Nutritive Value of Food per Pound and Average Food Consumption (1989–93)**

| Nutrient | Energy kcal | Protn g | Fat g | Carbo g | Choles mg | Ca mg | Phos mg | Iron mg | Potas mg | Sodium mg | VitA re | Thia mg | Ribo mg | Niacin mg | VitC mg | Food lb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Beef | 1,063 | 63.3 | 87.9 | 0.0 | 272 | 28 | 564 | 6.7 | 977 | 215 | 0 | 0.3 | 0.6 | 12.9 | 0.0 | 68.0 |
| Pork | 1,398 | 51.8 | 130.5 | 0.0 | 274 | 71 | 576 | 2.6 | 941 | 157 | 9 | 2.2 | 0.8 | 14.3 | 1.6 | 51.0 |
| Chicken | 665 | 57.4 | 46.4 | 0.4 | 281 | 35 | 467 | 4.1 | 593 | 219 | 720 | 0.2 | 0.6 | 20.8 | 8.3 | 73.4 |
| Turkey | 564 | 73.0 | 27.8 | 0.3 | 279 | 54 | 644 | 6.0 | 965 | 239 | 364 | 0.2 | 0.7 | 14.9 | 0.6 | 17.5 |
| Fish | 615 | 82.8 | 24.4 | 10.5 | 314 | 201 | 982 | 9.9 | 1,379 | 545 | 328 | 0.4 | 0.6 | 15.9 | 18.2 | 9.9 |
| C. fish | 794 | 121.4 | 29.4 | 0.0 | 296 | 750 | 1,425 | 7.3 | 1,613 | 2,187 | 168 | 0.2 | 0.7 | 46.6 | 0.0 | 5.1 |
| Eggs | 680 | 54.4 | 45.4 | 9.1 | 1,932 | 227 | 807 | 6.4 | 544 | 572 | 862 | 0.3 | 2.3 | 0.0 | 0.0 | 30.2 |
| Cheese | 1,782 | 105.3 | 145.8 | 8.1 | 462 | 3,062 | 2,884 | 2.4 | 599 | 4,714 | 1,361 | 0.2 | 1.7 | 0.0 | 0.0 | 25.1 |
| Milk | 251 | 14.9 | 12.1 | 21.4 | 47 | 547 | 428 | 0.2 | 694 | 225 | 200 | 0.2 | 0.7 | 0.4 | 3.7 | 220.0 |
| E. milk | 1,123 | 95.3 | 17.1 | 139.2 | 107 | 3,383 | 2,694 | 1.1 | 4,557 | 1,484 | 1,733 | 1.0 | 4.7 | 2.5 | 14.5 | 30.4 |
| Flour | 1,652 | 40.1 | 4.2 | 351.9 | 0 | 74 | 363 | 19.9 | 431 | 10 | 0 | 2.8 | 1.8 | 24.0 | 0.0 | 150.8 |
| Rice | 1,643 | 29.4 | 2.5 | 365.3 | 0 | 108 | 427 | 13.2 | 417 | 22 | 0 | 2.0 | 0.1 | 15.9 | 0.0 | 16.5 |
| Potato | 494 | 11.2 | 0.0 | 114.5 | 0 | 45 | 258 | 6.1 | 1,895 | 36 | 0 | 0.5 | 0.2 | 7.4 | 58.4 | 46.7 |
| Butter | 3,251 | 4.0 | 369.3 | 0.0 | 991 | 108 | 104 | 0.8 | 116 | 3,745 | 3,420 | 0.0 | 0.2 | 0.0 | 0.0 | 4.3 |
| Margarine | 2,410 | 3.0 | 270.6 | 3.0 | 0 | 108 | 83 | 0.2 | 153 | 4,316 | 4,504 | 0.0 | 0.1 | 0.0 | 0.0 | 10.7 |
| Oils | 4,007 | 0.0 | 453.6 | 0.0 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 50.2 |
| Apple | 263 | 0.0 | 0.0 | 69.0 | 0 | 33 | 33 | 0.7 | 523 | 0 | 23 | 0.1 | 0.1 | 0.0 | 26.3 | 18.9 |
| Orange | 208 | 3.5 | 0.0 | 51.9 | 0 | 180 | 62 | 0.3 | 821 | 0 | 93 | 0.4 | 0.2 | 1.4 | 242.4 | 13.4 |
| Banana | 418 | 4.0 | 4.0 | 107.4 | 0 | 28 | 92 | 1.6 | 1795 | 4 | 36 | 0.2 | 0.4 | 2.4 | 39.8 | 25.7 |
| Grape | 318 | 0.0 | 0.0 | 81.6 | 0 | 54 | 64 | 0.9 | 844 | 9 | 36 | 0.5 | 0.3 | 1.8 | 45.4 | 6.9 |
| Grapefruit | 151 | 3.8 | 0.0 | 37.8 | 0 | 53 | 38 | 0.4 | 631 | 0 | 4 | 0.2 | 0.1 | 1.1 | 155.0 | 5.7 |
| Lettuce | 59 | 4.2 | 0.8 | 9.3 | 0 | 86 | 91 | 2.3 | 717 | 41 | 150 | 0.2 | 0.1 | 0.8 | 17.7 | 24.8 |
| Tomato | 92 | 3.7 | 0.0 | 18.4 | 0 | 33 | 103 | 2.2 | 940 | 37 | 513 | 0.3 | 0.2 | 2.6 | 81.1 | 13.4 |
| Celery | 57 | 0.0 | 0.0 | 11.3 | 0 | 159 | 113 | 2.3 | 1293 | 397 | 57 | 0.1 | 0.1 | 1.1 | 34.0 | 6.4 |
| Onion | 156 | 5.7 | 0.0 | 34.0 | 0 | 113 | 130 | 1.7 | 703 | 9 | 0 | 0.3 | 0.1 | 0.6 | 36.9 | 14.6 |
| Carrot | 189 | 6.3 | 0.0 | 44.1 | 0 | 120 | 202 | 2.5 | 1468 | 158 | 12,758 | 0.4 | 0.3 | 4.4 | 44.1 | 7.8 |
| Juice | 203 | 2.7 | 0.0 | 48.9 | 0 | 45 | 65 | 1.1 | 815 | 6 | 69 | 0.3 | 0.1 | 1.5 | 171.0 | 56.4 |
| C. tomato | 95 | 3.8 | 1.9 | 18.9 | 0 | 117 | 87 | 2.8 | 1002 | 739 | 274 | 0.2 | 0.1 | 3.4 | 68.0 | 74.5 |
| C. peas | 307 | 21.3 | 2.7 | 56.0 | 0 | 91 | 304 | 4.3 | 784 | 993 | 350 | 0.6 | 0.3 | 3.2 | 42.7 | 1.9 |
| Cocktail | 343 | 1.8 | 0.0 | 90.0 | 0 | 34 | 38 | 1.4 | 395 | 18 | 53 | 0.2 | 0.1 | 1.7 | 17.2 | 2.3 |
| Peanut | 2,691 | 101.5 | 232.6 | 98.9 | 0 | 358 | 2,144 | 12.5 | 2,963 | 2,518 | 0 | 1.1 | 0.7 | 44.2 | 0.0 | 2.3 |
| Sugar | 1,746 | 0.0 | 0.0 | 451.3 | 0 | 7 | 0 | 0.2 | 16 | 11 | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 63.9 |
| Sweetener | 1,166 | 6.0 | 0.0 | 304.1 | 0 | 41 | 314 | 4.8 | 545 | 317 | 0 | 0.0 | 0.1 | 0.6 | 0.0 | 10.3 |
| Coffee | 0 | 0.0 | 0.0 | 0.0 | 0 | 10 | 5 | 0.0 | 312 | 5 | 0 | 0.0 | 0.1 | 1.0 | 0.0 | 7.6 |
| Frzn. D | 730 | 13.0 | 25.9 | 115.6 | 100 | 484 | 360 | 0.5 | 752 | 322 | 242 | 0.2 | 0.8 | 0.4 | 4.8 | 28.9 |

Note: The notations are Protn (protein), Choles (cholesterol), Carbo (carbohydrate), Ca (calcium), Phos (phosphorus), Potas (potassium), VitA (vitamin A), Thia (thiamin), Ribo (riboflavin), VitC (vitamin C), C. fish (canned fish), E. milk (evaporated and dry milk), Oils (salad and cooking oils), C. tomato (canned tomatoes), C. peas (canned peas), and Frzn. D (frozen dairy products). The units are kcal (food calorie), g (gram), mg (milligram), re (retinol equivalent), and lb (pound).

**Table 2. Food Share of Nutrient Based on Average Food Consumption (1989–93)**

| Nutrient | Energy | Protn | Fat | Carbo | Choles | Ca | Phos | Iron | Potas | Sodium | VitA | Thia | Ribo | Niacin | VitC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Percentage | | | | | | | |
| Beef | 6.53 | 13.02 | 10.94 | 0.00 | 12.05 | 0.51 | 7.37 | 8.17 | 6.78 | 3.34 | 0.00 | 2.39 | 4.44 | 9.93 | 0.00 |
| Pork | 6.45 | 7.99 | 12.20 | 0.00 | 9.12 | 0.96 | 5.65 | 2.36 | 4.91 | 1.83 | 0.11 | 14.21 | 4.28 | 8.25 | 0.29 |
| Chicken | 4.41 | 12.74 | 6.24 | 0.02 | 13.45 | 0.68 | 6.59 | 5.40 | 4.45 | 3.67 | 12.30 | 1.76 | 4.66 | 17.22 | 2.14 |
| Turkey | 0.89 | 3.87 | 0.89 | 0.00 | 3.19 | 0.25 | 2.17 | 1.90 | 1.73 | 0.96 | 1.49 | 0.51 | 1.39 | 2.94 | 0.04 |
| Fish | 0.55 | 2.48 | 0.44 | 0.09 | 2.03 | 0.53 | 1.87 | 1.76 | 1.40 | 1.23 | 0.76 | 0.50 | 0.60 | 1.78 | 0.64 |
| C. fish | 0.37 | 1.89 | 0.28 | 0.00 | 0.99 | 1.02 | 1.41 | 0.68 | 0.85 | 2.57 | 0.20 | 0.11 | 0.38 | 2.70 | 0.00 |
| Eggs | 1.85 | 4.97 | 2.51 | 0.23 | 38.00 | 1.82 | 4.68 | 3.44 | 1.68 | 3.94 | 6.05 | 1.03 | 7.45 | 0.00 | 0.00 |
| Cheese | 4.05 | 8.01 | 6.71 | 0.17 | 7.57 | 20.45 | 13.94 | 1.10 | 1.54 | 27.06 | 7.96 | 0.51 | 4.66 | 0.00 | 0.00 |
| Milk | 4.99 | 9.89 | 4.87 | 3.89 | 6.80 | 31.94 | 18.08 | 0.73 | 15.59 | 11.30 | 10.23 | 4.89 | 17.82 | 0.92 | 2.88 |
| E. milk | 3.09 | 8.77 | 0.95 | 3.50 | 2.11 | 27.34 | 15.75 | 0.61 | 14.15 | 10.31 | 12.27 | 3.99 | 15.54 | 0.84 | 1.55 |
| Flour | 22.52 | 18.30 | 1.15 | 43.86 | 0.00 | 2.97 | 10.53 | 53.93 | 6.64 | 0.35 | 0.00 | 53.53 | 29.66 | 40.90 | 0.00 |
| Rice | 2.45 | 1.47 | 0.07 | 4.99 | 0.00 | 0.47 | 1.35 | 3.93 | 0.70 | 0.08 | 0.00 | 4.13 | 0.26 | 2.97 | 0.00 |
| Potato | 2.08 | 1.59 | 0.00 | 4.42 | 0.00 | 0.56 | 2.32 | 5.09 | 9.03 | 0.38 | 0.00 | 2.90 | 0.80 | 3.90 | 9.59 |
| Butter | 1.28 | 0.05 | 2.93 | 0.00 | 2.81 | 0.12 | 0.09 | 0.06 | 0.05 | 3.71 | 3.45 | 0.02 | 0.08 | 0.00 | 0.00 |
| Margarine | 2.33 | 0.10 | 5.30 | 0.03 | 0.00 | 0.31 | 0.17 | 0.04 | 0.17 | 10.54 | 11.22 | 0.04 | 0.15 | 0.00 | 0.00 |
| Oils | 18.16 | 0.00 | 41.66 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Apple | 0.45 | 0.00 | 0.00 | 1.08 | 0.00 | 0.17 | 0.12 | 0.22 | 1.01 | 0.00 | 0.10 | 0.16 | 0.14 | 0.01 | 1.75 |
| Orange | 0.25 | 0.14 | 0.00 | 0.57 | 0.00 | 0.64 | 0.16 | 0.08 | 1.12 | 0.00 | 0.29 | 0.64 | 0.25 | 0.21 | 11.41 |
| Banana | 0.97 | 0.31 | 0.19 | 2.28 | 0.00 | 0.19 | 0.45 | 0.73 | 4.70 | 0.02 | 0.21 | 0.64 | 1.22 | 0.69 | 3.59 |
| Grape | 0.20 | 0.00 | 0.00 | 0.46 | 0.00 | 0.10 | 0.08 | 0.11 | 0.59 | 0.01 | 0.06 | 0.39 | 0.20 | 0.14 | 1.10 |
| Grapefruit | 0.08 | 0.07 | 0.00 | 0.18 | 0.00 | 0.08 | 0.04 | 0.04 | 0.37 | 0.00 | 0.01 | 0.11 | 0.05 | 0.07 | 3.11 |
| Lettuce | 0.13 | 0.32 | 0.04 | 0.19 | 0.00 | 0.57 | 0.43 | 1.01 | 1.81 | 0.23 | 0.86 | 0.66 | 0.36 | 0.24 | 1.54 |
| Tomato | 0.11 | 0.15 | 0.00 | 0.20 | 0.00 | 0.12 | 0.27 | 0.53 | 1.29 | 0.11 | 1.60 | 0.44 | 0.32 | 0.39 | 3.83 |
| Celery | 0.03 | 0.00 | 0.00 | 0.06 | 0.00 | 0.27 | 0.14 | 0.26 | 0.84 | 0.58 | 0.08 | 0.09 | 0.08 | 0.08 | 0.77 |
| Onion | 0.21 | 0.25 | 0.00 | 0.41 | 0.00 | 0.44 | 0.37 | 0.44 | 1.05 | 0.03 | 0.00 | 0.52 | 0.09 | 0.09 | 1.89 |
| Carrot | 0.13 | 0.15 | 0.00 | 0.29 | 0.00 | 0.25 | 0.30 | 0.35 | 1.17 | 0.28 | 23.28 | 0.43 | 0.22 | 0.39 | 1.22 |
| Juice | 1.04 | 0.47 | 0.00 | 2.28 | 0.00 | 0.67 | 0.71 | 1.11 | 4.69 | 0.08 | 0.90 | 2.30 | 0.70 | 0.93 | 33.94 |
| C. tomato | 0.64 | 0.85 | 0.26 | 1.16 | 0.00 | 2.32 | 1.24 | 3.79 | 7.62 | 12.56 | 4.75 | 1.95 | 1.07 | 2.86 | 17.83 |
| C. peas | 0.05 | 0.12 | 0.01 | 0.09 | 0.00 | 0.04 | 0.11 | 0.14 | 0.15 | 0.42 | 0.15 | 0.13 | 0.07 | 0.07 | 0.28 |
| Cocktail | 0.07 | 0.01 | 0.00 | 0.17 | 0.00 | 0.02 | 0.02 | 0.06 | 0.09 | 0.01 | 0.03 | 0.05 | 0.03 | 0.04 | 0.14 |
| Peanut | 0.56 | 0.71 | 0.98 | 0.19 | 0.00 | 0.22 | 0.95 | 0.52 | 0.70 | 1.32 | 0.00 | 0.33 | 0.18 | 1.15 | 0.00 |
| Sugar | 10.09 | 0.00 | 0.00 | 23.85 | 0.00 | 0.12 | 0.00 | 0.26 | 0.10 | 0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sweetener | 1.09 | 0.19 | 0.00 | 2.59 | 0.00 | 0.11 | 0.62 | 0.89 | 0.57 | 0.75 | 0.00 | 0.00 | 0.13 | 0.07 | 0.00 |
| Coffee | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.01 | 0.00 | 0.24 | 0.01 | 0.00 | 0.00 | 0.04 | 0.09 | 0.00 |
| Frzn. D | 1.91 | 1.14 | 1.37 | 2.76 | 1.88 | 3.72 | 2.00 | 0.24 | 2.22 | 2.13 | 1.63 | 0.63 | 2.66 | 0.13 | 0.48 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

Note: The notations are Protn (protein), Choles (cholesterol), Carbo (carbohydrate), Ca (calcium), Phos (phosphorus), Potas (potassium), VitA (vitamin A), Thia (thiamin), Ribo (riboflavin), VitC (vitamin C), C. fish (canned fish), E. milk (evaporated and dry milk), Oils (salad and cooking oils), C. tomato (canned tomatoes), C. peas (canned peas), and Frzn. D (frozen dairy products).

**Table 3. Own-Price and Income Elasticities Used in this Study**

| Food Category | Price Elasticity | | Income Elasticity | | Root-Mean-Square Error |
|---|---|---|---|---|---|
| | | | | | Percentage |
| Beef | –0.6212 | (0.0572) | 0.3923 | (0.1240) | 2.77 |
| Pork | –0.7281 | (0.0424) | 0.6593 | (0.1461) | 3.28 |
| Chicken | –0.3723 | (0.0560) | 0.0769 | (0.1884) | 3.88 |
| Turkey | –0.5345 | (0.1217) | –0.1267 | (0.3449) | 6.23 |
| Fish | 0.1212 | (0.1606) | 0.4290 | (0.3076) | 4.50 |
| C. fish | –0.3715 | (0.1486) | 0.3942 | (0.3621) | 4.28 |
| Eggs | –0.1103 | (0.0172) | 0.2865 | (0.0816) | 2.53 |
| Cheese | –0.2472 | (0.0833) | 0.4181 | (0.1934) | 3.75 |
| Milk | –0.0431 | (0.1259) | 0.1193 | (0.0718) | 1.38 |
| E.milk | –0.2764 | (0.5383) | 0.5151 | (0.2584) | 2.61 |
| Flour | –0.0777 | (0.1037) | 0.1314 | (0.1172) | 1.54 |
| Rice | 0.0661 | (0.1232) | 0.1475 | (0.4537) | 7.21 |
| Potato | –0.0983 | (0.0531) | 0.1100 | (0.3235) | 5.34 |
| Butter | –0.2428 | (0.1613) | 0.5386 | (0.3659) | 4.12 |
| Margarine | –0.0087 | (0.1470) | –0.3355 | (0.2494) | 3.05 |
| Oils | –0.1393 | (0.0650) | 0.4938 | (0.1713) | 2.53 |
| Apple | –0.1902 | (0.1295) | –0.3617 | (0.4206) | 7.38 |
| Orange | –0.8486 | (0.1154) | –0.1646 | (0.4765) | 7.34 |
| Banana | –0.4985 | (0.1337) | 0.0940 | (0.3658) | 4.68 |
| Grape | -1.1795 | (0.1591) | 0.5613 | (0.5710) | 7.99 |
| Grapefruit | –0.4546 | (0.1246) | –0.4896 | (0.5712) | 9.06 |
| Lettuce | –0.0904 | (0.0873) | 0.3720 | (0.2803) | 4.46 |
| Tomato | –0.6220 | (0.0845) | 0.9184 | (0.1906) | 3.26 |
| Celery | –0.0775 | (0.0638) | 0.7250 | (0.2283) | 2.85 |
| Onion | –0.2066 | (0.0474) | 0.0783 | (0.3184) | 4.53 |
| Carrot | –0.5339 | (0.2014) | 0.6750 | (0.5309) | 7.15 |
| Juice | –0.5575 | (0.1081) | 0.3664 | (0.5539) | 8.05 |
| C. tomato | –0.1688 | (0.0885) | 0.8684 | (0.2654) | 3.71 |
| C. peas | –0.5335 | (0.1580) | 0.6282 | (0.3599) | 5.16 |
| Cocktail | –0.7400 | (0.3536) | 0.7172 | (0.5848) | 6.03 |
| Peanut | –0.1685 | (0.0778) | 0.0992 | (0.2551) | 3.56 |
| Sugar | –0.0368 | (0.0220) | 0.0059 | (0.1761) | 2.68 |
| Sweetener | –0.0522 | (0.0938) | 0.4190 | (0.2659) | 4.28 |
| Coffee | –0.1761 | (0.0289) | 0.8176 | (0.2153) | 4.02 |
| Frzn. D | –0.0784 | (0.0955) | 0.2534 | (0.1366) | 1.39 |

Note: Compiled from Huang. The figures in parentheses are the standard errors of estimates. The notations are C. fish (canned fish), E. milk (evaporated and dry milk), Oils (salad and cooking oils), C. tomato (canned tomatoes), C. peas (canned peas), and Frzn. D (frozen dairy products).

symmetry, and Engel aggregation imposed at sample means. The food quantity data are compiled from *Food Consumption, Prices, and Expenditures*. Most food category price indexes are components of the consumer price index obtained from the U.S. Department of Labor. Per capita total expenditure is computed by dividing the personal consumption expenditures (obtained from the U.S. Department of Commerce) by the civilian population of fifty states on July 1 of each year.

The demand elasticities compiled for this study contain 1,260 estimates of own- and cross-price elasticities and income elasticities for thirty-five food categories. Among demand elasticity estimates, for example, the own-price elasticities for major meats are beef (–0.6212), pork (–0.7281), and chicken (–0.3723), and their corresponding income elasticities are beef (0.3923), pork (0.6593), and chicken (0.0769). The cross-price elasticities of beef in response to the price changes of pork and chicken are 0.1143 and 0.0183, indicating substitution. For illustration, only the own-price and income elasticities and the errors of simulation over the sample period as measures of fit are presented in table 3.

In the table, most own-price elasticities of major food categories in such food groups as meat and other animal proteins, fresh fruits, fresh vegetables, and processed fruits and vegetables have statistically significant estimates with an expected negative sign. The estimates for rice and fresh and frozen fish, however, are positive but not statistically significant. This poor estimate for fish is partly because of difficulty in defining prices and quantities for such a wide variety of fish species, and partly because large amounts of fish are consumed away from home and influenced by menu prices instead of the price of raw fish. Regarding the income elasticities, the statistically significant estimates are for beef, pork, eggs, cheese, evaporated and dry milk, salad and cooking oils, tomatoes, celery, canned tomatoes, and coffee. Although some income elasticity estimates for such foods as turkey are negative, this may not imply that the goods are inferior, because the estimates are not statistically significant. The simulation performance based on the calculated relative root-mean-square errors to sample means in the last column of the table indicates that the errors of simulated quantities demanded are less than 5% in most cases. The close correspondence between simulated values and sample observations indicates that this demand system is reliable for use in estimating nutrient elasticities.

Using the demand elasticities reported in Huang and the food shares of nutrients contained in table 2, nutrient elasticities on the basis of equation (6) are calculated. A set of nutrient elasticities, showing the effects on fifteen nutrients in response to changes in thirty-five food prices, and per capita income, are computed and reported in table 4. For example, a 1% increase in the price of beef (holding other prices and income the same) will affect the amount of all food consumption through the interdependent demand relationships. These changes in food consumption will reduce per capita food energy by 0.027%, protein by 0.091%, and fat by 0.025%, but vitamin A will increase by 0.064%. Although beef contains no vitamin A, its nutrient elasticity is influenced by cross-commodity effects, where the cross-price elasticities of carrot and chicken (both rich in vitamin A) in response to changing beef prices are positive. Among other nutrient elasticities in the table, a marginal 1% increase in the price of eggs may cause cholesterol to decrease by 0.031%. The same price change for carrots may cause vitamin A to decrease by 0.11%, while for oranges the price change may cause vitamin C to decrease by 0.194%. Finally, more nutrients are available with an increase in per capita income. The nutrient income elasticities are estimated in the range of 0.138 to 0.388 (last column in table 4).

All fifteen nutrients studied are consumed in decreasing or increasing amounts when food prices change, depending on how price changes manifest themselves through own- and cross-price elasticities. On the other hand, nutrient income elasticities reflect the combined effect of all income elasticities in the food demand system. These nutrient elasticities, which represent a total consumer nutrient profile, are useful in developing a model for studying food program effects on the quality of consumer diets. One way to accomplish this task is to simulate alternative food policy scenarios and explore the effects of food prices and income changes on nutrient availability of consumers.

For example, one may use nutrient income elasticities to evaluate the effects of income changes on consumer dietary quality. This is especially useful for monitoring the segment of the population whose incomes fall below the poverty level. Some government food assistance programs, such as the Food Stamp Program, increase the food purchasing power of low-income households by issuing monthly allotments of coupons to eligible households that can only be used to purchase food. Food policy decision makers, therefore, can use the information of nutrient income elasticities to assess the Food Stamp Program effects on the amount of nutrients welfare recipients receive.

## Conclusion

Americans seem increasingly concerned about their nutritional and health status. A better understanding of the economic forces that influence consumer food choice, and thus nutrient availability, is important to food policy decision makers. Food demand analysts need to broaden their theoretical and methodological base of research and provide timely information about the effects of economic factors on the nutritional status of consumers.

This study explores the linkage of the determinants of food choice with consumer nutrient availability by developing a procedure to measure changes in nutrient availability as the demand for food items changes. It uses demand elasticities from traditional demand analysis to

**Table 4. Nutrient Elasticities Based on Food Demand, 1953–90**

| Price | Beef | Pork | Chicken | Turkey | Fish | C. fish | Egg | Cheese | Milk | E. milk | Flour | Rice | Potato | Butter | Margar | Oils | Apple | Orange |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nutrient: | | | | | | | | | | | | | | | | | | |
| Energy | –0.027 | –0.011 | –0.003 | 0.006 | –0.017 | 0.002 | –0.008 | –0.039 | 0.003 | –0.004 | –0.026 | 0.003 | –0.010 | –0.009 | –0.005 | –0.021 | –0.009 | –0.016 |
| Protein | –0.091 | –0.028 | –0.030 | –0.014 | –0.015 | –0.006 | 0.003 | –0.037 | –0.018 | –0.049 | –0.032 | 0.008 | –0.003 | –0.004 | –0.015 | 0.027 | 0.003 | –0.017 |
| Fat | –0.025 | –0.020 | –0.009 | 0.015 | –0.016 | 0.013 | –0.003 | –0.054 | 0.028 | 0.018 | –0.023 | –0.002 | –0.013 | –0.022 | 0.003 | –0.056 | –0.019 | –0.022 |
| Carbohydrate | –0.009 | 0.004 | 0.011 | 0.002 | –0.019 | –0.007 | –0.016 | –0.024 | –0.016 | –0.014 | –0.025 | 0.005 | –0.010 | 0.004 | –0.009 | –0.000 | –0.002 | –0.011 |
| Cholesterol | –0.025 | –0.031 | –0.021 | –0.013 | –0.008 | –0.016 | –0.031 | –0.030 | 0.010 | 0.000 | –0.052 | 0.004 | 0.003 | –0.018 | 0.002 | –0.001 | –0.008 | –0.011 |
| Calcium | –0.078 | –0.028 | 0.039 | 0.004 | –0.041 | –0.019 | 0.026 | –0.094 | –0.072 | –0.138 | –0.021 | 0.011 | –0.007 | –0.008 | –0.026 | 0.045 | 0.009 | –0.041 |
| Phosphorus | –0.080 | –0.032 | 0.002 | –0.004 | –0.024 | –0.010 | 0.011 | –0.061 | –0.040 | –0.085 | –0.033 | 0.012 | –0.005 | –0.010 | –0.018 | 0.028 | 0.005 | –0.026 |
| Iron | –0.096 | –0.000 | 0.000 | –0.006 | –0.025 | –0.010 | –0.023 | –0.023 | 0.016 | –0.017 | –0.038 | 0.011 | –0.009 | –0.004 | –0.019 | 0.017 | –0.005 | –0.002 |
| Potassium | –0.076 | –0.058 | 0.043 | –0.023 | –0.042 | –0.023 | 0.005 | –0.032 | –0.023 | –0.083 | 0.021 | –0.014 | –0.011 | 0.030 | –0.041 | 0.054 | 0.008 | –0.044 |
| Sodium | –0.140 | –0.039 | 0.034 | –0.005 | –0.051 | –0.036 | 0.005 | –0.077 | 0.069 | –0.166 | –0.022 | 0.016 | –0.005 | –0.024 | –0.040 | 0.050 | 0.014 | –0.022 |
| Vitamin A | 0.064 | –0.004 | 0.061 | –0.060 | –0.114 | –0.014 | 0.011 | –0.086 | 0.090 | 0.072 | –0.128 | 0.033 | 0.015 | 0.036 | –0.043 | 0.009 | 0.032 | 0.014 |
| Thiamin | –0.041 | –0.099 | 0.015 | 0.002 | –0.022 | –0.005 | –0.020 | –0.032 | –0.001 | –0.019 | –0.033 | 0.012 | –0.012 | 0.002 | –0.015 | 0.021 | –0.005 | –0.011 |
| Riboflavin | –0.074 | –0.029 | 0.019 | –0.007 | –0.033 | –0.016 | –0.002 | –0.051 | –0.037 | –0.058 | –0.023 | 0.001 | –0.005 | 0.014 | –0.020 | 0.036 | 0.003 | –0.016 |
| Niacin | –0.072 | –0.031 | –0.048 | –0.011 | –0.020 | –0.009 | –0.009 | –0.016 | 0.008 | –0.007 | –0.022 | 0.001 | –0.005 | 0.007 | –0.018 | 0.027 | –0.004 | –0.008 |
| Vitamin C | –0.135 | –0.154 | 0.112 | –0.032 | –0.019 | –0.012 | –0.066 | –0.049 | 0.063 | –0.067 | 0.097 | –0.037 | –0.043 | 0.031 | –0.056 | 0.067 | –0.007 | –0.194 |

| Price | Banana | Grape | Grapef | Lettuce | Tomato | Celery | Onion | Carrot | Juice | C. tomato | C. peas | Cocktl | Peanut | Sugar | Sweeten | Coffee | Frzn. D | Income |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nutrient: | | | | | | | | | | | | | | | | | | |
| Energy | –0.007 | –0.013 | –0.011 | 0.007 | –0.009 | –0.007 | –0.001 | –0.002 | –0.002 | 0.002 | 0.001 | 0.001 | 0.008 | –0.006 | –0.022 | 0.001 | 0.017 | 0.266 |
| Protein | –0.010 | –0.011 | –0.008 | 0.009 | 0.007 | –0.010 | –0.003 | 0.005 | 0.002 | –0.003 | –0.007 | 0.002 | 0.001 | 0.000 | –0.028 | 0.005 | 0.022 | 0.277 |
| Fat | –0.004 | –0.009 | –0.016 | 0.011 | –0.028 | –0.008 | –0.002 | –0.002 | 0.007 | 0.005 | 0.005 | –0.000 | 0.013 | 0.005 | –0.038 | 0.003 | 0.002 | 0.388 |
| Carbohydrate | –0.012 | –0.019 | –0.007 | 0.002 | 0.004 | –0.005 | –0.001 | –0.004 | –0.011 | –0.000 | –0.000 | 0.001 | 0.005 | –0.019 | –0.004 | –0.002 | 0.031 | 0.138 |
| Cholesterol | –0.001 | 0.003 | –0.005 | 0.007 | 0.002 | 0.000 | 0.002 | 0.002 | –0.009 | –0.000 | –0.000 | 0.005 | –0.001 | 0.002 | –0.004 | 0.010 | 0.003 | 0.306 |
| Calcium | –0.022 | –0.023 | –0.013 | 0.021 | 0.010 | –0.021 | –0.006 | 0.023 | –0.000 | –0.008 | –0.017 | 0.000 | –0.003 | 0.008 | –0.073 | 0.013 | 0.024 | 0.329 |
| Phosphorus | –0.015 | –0.016 | –0.010 | 0.013 | 0.006 | –0.014 | –0.003 | 0.011 | –0.001 | –0.005 | –0.010 | 0.001 | –0.001 | 0.004 | –0.045 | 0.008 | 0.020 | 0.305 |
| Iron | –0.010 | –0.019 | –0.006 | –0.003 | –0.006 | –0.005 | –0.000 | –0.004 | –0.001 | –0.004 | 0.002 | –0.001 | 0.008 | –0.007 | –0.012 | –0.000 | 0.035 | 0.217 |
| Potassium | –0.049 | –0.021 | –0.015 | 0.010 | –0.006 | –0.022 | –0.007 | 0.011 | –0.018 | –0.017 | –0.008 | 0.002 | 0.011 | –0.005 | –0.021 | –0.000 | 0.045 | 0.321 |
| Sodium | –0.023 | –0.030 | 0.006 | 0.004 | –0.022 | –0.016 | –0.007 | 0.013 | 0.006 | –0.029 | 0.004 | 0.003 | 0.018 | 0.013 | –0.078 | 0.021 | 0.018 | 0.349 |
| Vitamin A | –0.080 | –0.028 | 0.036 | 0.022 | 0.083 | 0.006 | 0.032 | –0.110 | –0.041 | –0.002 | 0.011 | 0.000 | 0.046 | –0.002 | –0.067 | 0.001 | 0.077 | 0.344 |
| Thiamin | –0.007 | –0.019 | –0.009 | –0.000 | 0.004 | –0.006 | 0.000 | –0.004 | –0.012 | –0.001 | –0.001 | 0.001 | 0.011 | –0.012 | –0.009 | –0.001 | 0.038 | 0.257 |
| Riboflavin | –0.016 | –0.016 | –0.010 | 0.009 | 0.016 | –0.013 | –0.003 | 0.009 | 0.001 | –0.003 | –0.012 | 0.003 | 0.002 | –0.005 | –0.031 | 0.003 | 0.037 | 0.262 |
| Niacin | –0.012 | –0.012 | –0.003 | 0.002 | 0.009 | –0.004 | –0.002 | –0.001 | 0.005 | –0.003 | 0.002 | 0.001 | 0.007 | –0.009 | –0.013 | 0.001 | 0.034 | 0.229 |
| Vitamin C | –0.053 | –0.028 | –0.041 | 0.016 | –0.066 | –0.023 | –0.012 | 0.002 | –0.193 | –0.026 | 0.013 | 0.003 | 0.056 | –0.024 | 0.034 | –0.010 | 0.060 | 0.337 |

Note: The notations are C. fish (canned fish), E. milk (evaporated and dry milk), Margar (margarine), Oils (salad and cooking oils), Grapef (grapefruits), C. tomato (canned tomatoes), C. peas (canned peas), Cocktl (fruit cocktail), Sweeten (sweeteners), and Frzn. D (frozen dairy products).

estimate elasticities of changes in the nutritional content of consumer diets. The unique feature of the procedure is that existing interdependent demand relationships can be incorporated into measuring the changes in nutrients available to consumers. The procedure was applied to estimating nutrient elasticities for fifteen nutrients in response to changes in thirty-five food prices and per capita income. These nutrient elasticities, when viewed as a total consumer nutrient profile, provide useful information for food policy decision makers to assess the food program effects on the quality of consumer diets.

To develop a comprehensive food demand and nutrition study, some further collaborative research between economists and nutritionists is needed. One problem encountered in this study is the difficulty in obtaining accurate nutrient information corresponding to food disappearance data commonly used by demand analysts. The disappearance data is normally compiled as the residual of the food commodity supply-utilization table to reflect disappearance of food into the marketing system. Most available nutrition information, however, gives detailed nutritive values of the amount of edible portion of food products but not of disappearance quantities. To justify the use of these nutritive values, a fixed proportion between the amount of edible portion of a particular food and its disappearance quantity has to be assumed. Accordingly, the relative changes in quantities, and thus the measured nutrient elasticities generated from either edible portion data or disappearance data, should be the same. In addition, the use of disappearance data hardly can distinguish nutritive values from different food preparation methods. For example, chicken fried in animal fat or vegetable oils has far different properties from those of roasted chicken.

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