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Julie A. Caswell

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PART FOUR: Inputs to Valuation Studies

19. Adding Nutritional Quality to Analysis of Meat Demand

Guijing Wang and Wen S. Chern

Food Marketing Policy Center
Department of Agricultural and Resource Economics
University of Connecticut

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Guijing Wang

Wen S. Chern

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19

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Guijing Wang and Wen S. Chern[1]

Numerous meat demand studies have been undertaken in the past several decades, providing many insights into the effects of conventional factors such as price and income on meat demand. However, other factors such as nutritional quality have been overlooked. Price variations across consumers owing to quality differences have not been well understood. This chapter attempts to complement existing studies by evaluating meat demand from a nutritional quality perspective. In addition, from public health perspectives such as health promotion and disease prevention, it is important to understand the nutritional aspects of food quality.

In this chapter, nutritional quality indexes of ten nutrients including seven essential nutrients (niacin, vitamin-B6, vitamin-B12, phosphorus, magnesium, iron, and zinc) and three undesirable nutrients (fat, saturated fat, and cholesterol) in five meats (beef, pork, lunch meat, poultry, and fish) are derived and discussed using data from the 1987-88 Nationwide Food Consumption Survey (NFCS). Unlike the conventional studies of Marshallian demand analyzing the quantity and price relationship, this study focuses on the relationship between price and quality attributes. This relationship is specified as a multiple regression model by combining the approach of Houthakker (1952) and hedonic methodology. Additionally, the heterogeneous nature of a food is detected by the diagnostics procedure developed by Belsley (1991). One important econometric issue, related to multicollinearity among nutrient attributes, is also appropriately addressed for model estimation.

The proposed methodology is important both theoretically and empirically. Traditional consumer theory assumes that commodities are homogenous and prices are exogenous to consumers. These assumptions may be severely violated if broadly aggregated survey data are used. If price variations in cross-sectional data are mainly due to commodity heterogeneity (quality variations), the classical consumer demand theory may not be applied. Thus, a well defined nutritional quality index and a specification of the price-quality relationship are particularly useful to understand consumers' food demand behavior.

Furthermore, future efforts toward nutritional improvement are striving for food quality rather than quantity. The information provided by this approach is of great interest to consumers since they know what they are paying for and what is the right food combination. Health care professionals can use the information to design appropriate diet plans for consumers and to initiate nutritional education programs. Food producers can utilize the information to improve nutritional quality of food. Government food agencies can propose appropriate food polices and assistance programs according to consumer nutritional intake and nutritional quality information.

Approaches to Studying Meat Demand

Meat and poultry consumption constitutes the largest proportion of the food budget in the United States. According to the NFCS, for an average household in 1987-88, meat expenditures (excluding poultry and fish) accounted for 21 percent of the budget of total food consumed at home, the largest budget share among 19 food groups covered in the survey. The expenditure share of poultry and fish combined was 11 percent. The significant budget allocation to meat, poultry, and fish explains why the demand for these food groups has been studied extensively in the past several decades.

During the early 1960s, meat demand became less price elastic in the United States. By examining the demand relations for beef, pork, and broilers during 1949-1956 (period 1) and 1956-1964 (period 2), Tomek (1965) found that price elasticities were less elastic in period 2 than in period 1. More importantly, he pointed out that the change in elasticity may be due to a quality change in the product, although he did not define and incorporate quality factors in his study.

In recent years, meat demand studies have focused on the flexible demand system and the impacts of demographic variables. Examples of these studies include Christensen and Manser (1977), Chalfant (1987), and Heien and Pompelli (1988). Although many of these studies mentioned product quality characteristics to provide useful insights in explaining meat consumption behavior, none incorporated meat quality into the demand analysis.

Chalfant and Alston (1988) studied structural changes in meat demand, accounting for consumer taste changes. They argued that the inadequacy of prices and expenditures in explaining observed patterns of meat consumption was due to specification errors in demand models. Other studies, e.g., Eales and Unnevehr (1993) have found significant structural changes. One major reason for these conflicting results may be that the price used in classical demand models is incapable of accounting for quality variations across consumers and over time. Alston and Chalfant (1991) argued further the importance of correct model specification. However, data on and measurement of such information as the nutritional quality of meat are essential.

One may argue that consumers are ignorant about nutrients contained in meats and that the nutritional quality of meat is irrelevant as a determinant of meat demand. However, nutrients are the basic physical quality attributes of food. The nutritional quality of meat is associated with its price. Understanding the nutritional quality of meat will enable us to distinguish consumption responses resulting from changes in price and quality. Moreover, the nutritional quality analysis of food will provide useful information for evaluating the American diet.

Houthakker was among the first to discuss commodity quality in analyzing consumer behavior. Houthakker (1952) defined "quality elasticities" as the proportionate rise in the average price per unit associated with a small proportionate rise in income. Cox and Wohlgenant (1986) and Deaton (1990) have made further contributions to the attempt to incorporate quality effects into theoretical and empirical food demand models. However, they did not define and measure food quality explicitly.

More recently, a number of studies have investigated the impacts of product attributes and nutritional information on the demand for food. Brown and Schrader (1990) studied cholesterol information and shell egg consumption. Their cholesterol information index was examined further by Capps and Schmitz (1991) in discussing health and nutrition factors in food demand analysis, and by Yen and Chern (1992) in their study of fats and oils consumption. Schmitz (1992) investigated the impact of nutritional information on demand for dairy products. Results from these studies indicated that consumer health and nutrition concerns had significant effects on food demand. Although these studies emphasized the importance of food attributes and nutritional information, the nutritional quality of food has never been quantified and incorporated in food demand analysis.

Methodology

Developing an Index of the Nutritional Quality of Meat

Food quality can be measured by nutritional content. Hansen et al. (1979) developed an index of nutritional quality (INQ). The index expresses the nutritional quality of a food by comparing the nutrients in the food to the calories it contains. In order to compute the INQ, nutrient standards must be determined first. According to Hansen et al. (1979), a nutrient standard is the amount of nutrient needed to meet a human's daily need in order to maintain good health.

The Recommended Dietary Allowances (RDA) can serve as the standards. For example, the standard for vitamin-B6 is 2 mg for males above 15 years old according to the 10th edition of the RDA (National Academy of Science 1989).

Based on the nutrient standard, the percentage of the standard of nutrient j in meat i, W_{ij}, is calculated for each meat by:[2]

$$W_{ij} = \frac{N_{ij}}{S_j} \times 100\% \ , \tag{1}$$

where N_{ij} is the amount of nutrient j contained per unit of meat i, and S_j is the standard for nutrient j.

The INQ of nutrient j in meat i is expressed as the ratio of its percentage standard of nutrient j, W_{ij}, relative to its percentage standard of energy (calories), W_{ie}. It is expressed as:

$$INQ_{ij} = \frac{W_{ij}}{W_{ie}} \ . \tag{2}$$

For each nutrient in a meat, an INQ can be computed. Note that the INQ_{ij}s vary from one household to another because of the different compositions of meat and/or different meals or different ways of cooking with the same meat. For example, beef includes steak, roast, ground beef, etc., and the composition affects the amount of various nutrients and yields different INQs for different households. In fact, if the same meat contained the same nutrients, there will be exact multicollinearity among nutrients over households. From this approach, the INQ for energy in any meat is unity. The INQs for other nutrients may be smaller or larger than unity. For a desirable nutrient, a meat having an INQ of 1.0 or greater for that nutrient is of good quality in the nutrient. Otherwise the meat is of low nutritional quality. For undesirable nutrients such as fat and cholesterol, the INQs have an opposite meaning. Here, greater INQs for fat and cholesterol imply the meat is of lower quality.

The Price-Quality Relationship

In a cross-sectional demand analysis, prices are usually derived by dividing aggregated expenditures by quantities purchased. Thus, prices are actually the average unit values. They are determined by the composition of the subcommodities in the groups. For example, beef price is the average price of variety beef such as steak and roast. Therefore, a large part of the variation in prices may be due to the choice of different qualities of a commodity. This implies that price cannot be regarded as exogenous to consumers (Pudney 1989). Houthakker (1952) pointed out that:

> Apparent differences in prices may occur if goods are available in a variety of qualities, . . ., if they [consumer unit] do pay different amounts per unit for the same good the qualities bought must be different (pp. 2, 6).

Deaton (1990) also noted:

> Commodities are considered as collections of heterogeneous goods within which consumers can choose more or less expensive items, so that the unit value of a commodity, the price paid per physical unit, is a matter of choice (p. 282).

Therefore, specifying and estimating the price-quality relationship is important in understanding consumption behavior. Houthakker modeled the price-quality relationship as:

(3) $$p_i = \alpha_i + \beta_i \log(X) + e_i ,$$

where p_i is the average price of the i_{th} good defined by dividing expenditure by quantity, X is per capita income, α and β are parameters to be estimated, and e is the error term. A positive estimate of β is expected, which implies that higher income consumers purchase higher quality commodities.

As shown by Deaton (1990) food quality varies with income, household characteristics, and other determinants of food consumption. Following his approach, a price-quality function for this study is specified as:

(4) $$p_i = \alpha_i + \beta_i \log(FC) + \sum_j \gamma_{ij} z_j + e_i ,$$

where p is the same as defined as Houthakker; FC is the per capita total food cost (including food cost at- and away-from-home); z includes indexes of nutritional quality (INQ) of meat and demographic variables; α, β, and γ are parameters to be estimated; and e is the error term.

The inclusion of INQs in the price-quality equation for a meat depends on the results of the collinearity diagnostic testing described in the following section. If an equation includes a fat or cholesterol index, the expected sign of the estimated coefficient is negative. This implies that a higher fat or cholesterol index in a meat indicates lower quality of the meat. The signs of estimated coefficients of other included INQs are indeterminate.

The demographic variables include the educational levels, race, age, and status of household head, and food stamp participation. Because it is reasonable to assume that a female head of household is more responsible for meal planning, the household head refers to the female head except when the household does not have a female head. The age is the actual years of the household head. The specification of other categorical (0,1) variables are:

ED1 = 1 if household head completed less than 9 years of school,
ED2 = 1 if household head completed 1-4 years of college,
ED3 = 1 if household head completed more than 4 years of college,
Black = 1 if household head is black,
Food Stamp = 1 if household is currently receiving food stamps, and
Female Headed = 1 if household is only female headed.

All three educational levels are used in the regression. Note that the singularity problem is avoided by leaving out the households whose heads completed 10-12 years of school. The educational level is hypothesized to be positively related to food quality, i.e., consumers with higher educational levels consume higher quality food than less educated consumers. The age of household head is expected to have a positive estimated coefficient. This means that older household heads are more knowledgeable and aware of food quality. Food stamp recipients should have a negative coefficient since they are low income consumers. The signs of the coefficients on other demographic variables are indeterminate.

Diagnostic Test of INQs

There are ten nutrients under investigation in this study. In the price-quality relationship, all ten INQs should be included. The relationship between the ten INQs represents the heterogeneity characteristics of a food. The more heterogenous a meat, the more quality variation there will be in the meat. Moreover, the inclusion of all the INQs may result in serious estimation problems related to multicollinearity. Although the INQs in a meat vary between households as mentioned previously, a high collinearity between them is often encountered. It is obvious that for a more homogeneous commodity, a higher collinearity between the INQs should be expected. For regression, inefficient estimates based on least squares will occur if the collinearity is severe. Therefore, conducting a diagnostic test for the INQs is necessary to understanding the heterogeneous nature of food and selecting an appropriate subset of INQs for estimating the price-quality relationship accurately.

There are many procedures proposed and commonly employed to detect collinearity, such as examination of the correlation matrix and the principal component method. The procedure followed here is the scaled condition index and variance-decomposition proportions method of Belsley (1991).[3] This method provides an effective way of diagnosing the presence of and variables involved in collinearity. It is more satisfactory in detecting multicollinearity, although it is less commonly used in the literature (Kennedy 1987).

The Belsley method is composed of two major steps. The first determines the number of collinear relations by computing condition indexes. The second is to determine variable involvement by variance-decomposition proportions. These two steps are delineated below.

Let X be a m by n data matrix, it is always possible to decompose X as:

$$(5) \qquad X = USV',$$

where U is a m by n and V is a n by n matrix, both U and V are orthogonal matrixes, and S is a n by n diagonal matrix:

$$S = \begin{bmatrix} s_1 & & & & & \\ & s_2 & & & & \\ & & \cdot & & & \\ & & & \cdot & & \\ & & & & \cdot & \\ & & & & & s_n \end{bmatrix}.$$

The s_i's are called singular values of X and are unique.

Let Y be the dependent variable and b be the vector of the estimated coefficients from a least squares regression of Y on X. The variance-covariance matrix of b can be written as:

$$(6) \qquad var(b) = \delta^2(x'x)^{-1} = \delta^2 vs^{-2}v',$$

where σ^2 is the estimated variance of the disturbance in the regression. Apparently, the singular values are related to the precision of coefficient estimates from the least squares method.

The condition index is defined as

$$(7) \qquad \eta_k = \frac{s_{max}}{s_k}, \quad k = 1,...n,$$

where S_{max} is the maximum singular value.

Belsley pointed out that the condition index is meaningful only if the columns of the data matrix are scaled to have equal length. As a matter of practice, scaling each column of X to have a unity length is preferable and employed in this study. He suggested that a value of the condition index above 30 indicates a moderate to strong collinearity condition. The number of large condition indexes (> 30) indicates the number of collinear relationships among the columns of the data matrix, X.

The next step is to determine how many and which variables are involved in a collinear relation. For this purpose, the variance-decomposition proportions are derived. The proportion of the variance of a regression coefficient k associated with a condition index j are computed by:

$$\pi_{jk} = \frac{w_{kj}}{w_k}, \quad k = 1,...,n, \tag{8}$$

$$\textit{where} \qquad w_{kj} = \frac{V_{kj}^2}{s_j^2}, \quad w_k = \sum_{j=1}^{n} w_{kj},$$

and where V_{kj} is the element of the orthogonal matrix V at the k^{th} row and j^{th} column, and S_j is the j^{th} singular value.

A large proportion of the variance of a coefficient being associated with a large scaled condition index is an indicator that the variable is involved in a collinear relationship with other variables. It is apparent that at least two variables are involved if a collinear relationship is present. This procedure is applied to detect the collinearity problems among the INQs for each meat. The INQs involved in highly collinear relationships are eliminated accordingly. Belsley shows that it is not always possible to determine from the variance-decomposition proportions alone exactly which variables are involved in collinear relationships. For example, there may not be two or more high variance-decomposition proportions associated with a high scaled condition index.

For this situation, auxiliary regressions can be formed to show the near dependencies in greater detail. For example, for a subset of variables which are suspected to be involved in dependencies, regressing one variable on other remaining variables can signal variable involvement. This also shows whether the variations of the deleted variables can be represented by the remaining variables. In this chapter, the auxiliary regression was only formed for fat and saturated fat in beef, pork, lunch meat, and poultry because fat and saturated fat in these foods are the most important attributes consumers are concerned about. Unfortunately, fat and saturated fat are eliminated from the analysis based on the collinearity diagnosis.

Data

Data used in this study is obtained from the 1987-88 Nationwide Food Consumption Survey (NFCS) sponsored by the U.S. Department of Agriculture.

The survey was conducted between April 1987 and March 1988. This cross-sectional data set provides the food consumption, cost, and nutrient contents of the food on a weekly basis for 4,273 housekeeping households in the U.S. These households are defined as those with at least one member having ten or more meals from the household food supply during the survey week. Among these households, only those who consumed a meat are used for this study.

A group of five meats (beef, pork, lunch meat, poultry, and fish) is defined as a food bundle. Lunch meat includes frankfurters, hot dogs, and other lunch meat except boiled ham and roast beef. The five meats are selected for this study because they contain similar nutritive values. Close substitutional and complementary relationships are also expected among these food items.

The sample means of per capita food consumption, prices, and sample sizes for different household groups are highlighted in Table 19.1. The price is derived by dividing food cost (expenditure) by quantity consumed. Interestingly, comparing the quantity and price between different household groups, the larger quantities are almost always associated with lower prices. For example, the consumers with lower educational levels consumed more beef and paid much lower unit price.[4] This is a strong indicator of quality differences among foods consumed by different household groups.

The ten nutrients investigated in this study are fat, saturated fat, cholesterol, niacin, vitamin-B6, vitamin-B12, phosphorus, magnesium, iron, and zinc.[5] The selection of these nutrients is based on the fact that they are commonly contained in and mainly provided by the meat-poultry-fish food group in the American diet. According to the Human Nutrition Information Service (1990), more than 44 percent of vitamin-B12, zinc, and niacin are provided by this food group for women aged 19 to 50 years. More than 25 percent of vitamin-B6, phosphorus, and iron consumed by the women are derived from this group, while the group provides 18 percent of the women's magnesium consumption. Fat and cholesterol in these meats are probably the major attributes which are well recognized and of concern to consumers.

The nutrient standards for these ten nutrients are calculated based on the 10th edition of Recommended Dietary Allowance (RDA). Since other data are converted into the base of a standard person, the nutrient standards are derived by averaging the RDAs for male and female. The RDAs (standards) for energy, niacin, vitamin-B6, vitamin-B12, phosphorus, magnesium, iron, and zinc are 2,305 (kcal), 16.3 (mg), 1.74 (mg), 2 (mg), 1,040 (mg), 314 (mg), 12.4 (mg), and 13.5 (mg), respectively. The standard for cholesterol is daily consumption of 300 (mg) or less for adults (NAS 1989: 50). For fat, the standard is computed as follows. A gram of fat provides 9 calories of energy (Drummond 1989: 39). The amount of energy that comes from fat and saturated fat should be less than 30 percent and 10 percent of total energy, respectively (NAS 1989: 49). Using the standard of energy (2,305 kcal), the standards of fat and saturated fat are 76.8 (g) and 25.6 (g), respectively.

TABLE 19.1 Average Food Consumption Per Capita Per Week and Prices for Different Household Groups

Item	Beef		Pork		Lunch Meat		Poultry		Fish	
	Q[a]	P[b]	Q	P	Q	P	Q	P	Q	P
Total Sample	1.76 (3594)[c]	1.91	1.18 (2975)	2.08	0.59 (2755)	2.11	1.70 (3108)	1.40	0.89 (2238)	2.92
Education:										
ED1	1.87 (471)	1.71	1.44 (393)	1.81	0.65 (378)	1.90	1.82 (437)	1.11	0.89 (262)	2.65
ED2	1.59 (1105)	2.03	1.02 (878)	2.18	0.55 (788)	2.25	1.64 (971)	1.55 (727)	0.90	3.14
ED3	1.47 (210)	2.30	0.98 (171)	2.46	0.45 (153)	2.31	1.60 (199)	1.60 (158)	0.91	3.38
Food Stamp Participant:										
Yes	1.92 (266)	1.56	1.36 (227)	1.80	0.65 (231)	1.87	1.62 (239)	1.10	1.01 (159)	2.30
No	1.75 (3328)	1.94	1.16 (2748)	2.10	0.58 (2524)	2.14	1.70 (2826)	1.43	0.88 (2079)	2.97

Race:										
Black	2.07	1.70	1.77	1.74	0.74	1.77	2.18	0.94	1.48	2.26
	(404)		(377)		(349)		(433)	(268)		
Other	1.72	1.93	1.09	2.12	0.57	2.16	1.62	1.48	0.81	3.01
	(3190)		(2598)		(2406)		(2675)	(1970)		
Household Head Status:										
Female Headed	1.82	1.86	1.24	2.05	0.64	2.05	1.90	1.41	0.97	2.77
	(819)		(662)		(616)		(770)		(488)	
Other	1.75	1.92	1.16	2.08	0.57	2.13	1.63	1.40	0.87	2.96
	(2775)		(2313)		(2139)		(2338)		(1750)	

[a]Q = quantity (lb).
[b]P = price ($/lb).
[c]Numbers in parentheses are sample sizes.

Analysis of Nutritional Quality

The sample means of the INQs of meats for the total sample are reported in Table 19.2. All five products are of good quality in niacin and vitamin-B12. Fish is of good quality in all nutrients except cholesterol. Except fish, all meats are not of good quality in magnesium. Pork is not a good source of iron. All the meats except fish provide a high level of fat relative to their energy content. Pork has the highest index of fat while poultry has the largest index of cholesterol. While the INQ of saturated fat is higher than the INQ of fat for beef, pork, and lunch meat, the opposite is true for poultry and fish. This is consistent with the fact that poultry and fish contain a more balanced fat composition[6] (Drummond 1989).

Table 19.3 presents the average INQs of meats for different household groups by educational levels.[7] In terms of fat and saturated fat, households with a well-educated household head consume higher quality meat because their INQs of fat and saturated fat are lower than the other households. This is particularly true in the case of pork and poultry. Fat and saturated fat intakes are lower for well-educated consumers since they consume less meat with the lower INQs of fat and saturated fat (Tables 19.1 and 19.2). However, in terms of cholesterol, the above intake pattern does not hold. For other major nutrients, households with a well-educated head have a tendency to consume meats with higher INQs.

TABLE 19.2 Means of Nutritional Quality Indexes of Meat and Related Products

Nutrients	Beef (3594)[a]	Pork (2975)	Lunch Meat (2755)	Poultry (3108)	Fish (2238)
Energy	1.00	1.00	1.00	1.00	1.00
Fat	2.36	2.65	2.57	1.81	0.66
Saturated Fat	2.85	2.88	2.84	1.55	0.43
Cholesterol	2.26	1.54	1.71	3.17	3.12
Niacin	1.98	1.58	1.54	4.40	6.56
Vitamin-B6	0.93	1.02	0.89	2.23	1.92
Vitamin-B12	9.32	2.64	6.15	2.49	26.22
Phosphorus	1.32	1.17	0.86	1.67	3.77
Magnesium	0.51	0.32	0.31	0.70	1.99
Iron	1.41	0.45	0.99	1.07	2.03
Zinc	2.70	0.94	1.19	1.40	2.23

[a]Numbers in parentheses are sample sizes.

TABLE 19.3 Means of Nutritional Quality Indexes of Meats for Different Consumer Groups by Educational Levels

Nutrients	Beef			Pork			Lunch Meat			Poultry			Fish		
	ED1 (471)[a]	ED2 (1105)	ED3 (210)	ED1 (393)	ED2 (878)	ED3 (171)	ED1 (378)	ED2 (788)	ED3 (153)	ED1 (437)	ED2 (971)	ED3 (199)	ED1 (262)	ED2 (727)	ED3 (158)
Energy	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fat	2.39	2.33	2.33	2.72	2.65	2.58	2.59	2.55	2.52	1.90	1.75	.74	0.80	0.61	0.64
Saturated Fat	2.89	2.81	2.80	2.96	2.87	2.78	2.88	2.81	2.76	1.62	1.49	1.49	0.53	0.40	0.40
Cholesterol	2.26	2.27	2.27	1.50	1.55	1.61	1.68	1.74	1.86	3.22	3.16	3.19	3.30	3.18	3.23
Niacin	1.94	2.01	2.00	1.39	1.62	1.80	1.45	1.61	1.71	3.95	4.70	4.68	5.68	6.78	7.01
Vitamin-B6	0.90	0.96	0.99	0.88	1.04	1.17	0.87	0.93	0.97	2.00	2.38	2.42	2.00	1.92	1.83
Vitamin-B12	9.27	9.39	9.50	2.43	2.68	2.88	5.95	6.33	6.90	2.49	2.49	2.63	22.75	29.46	26.61
Phosphorus	1.30	1.33	1.36	1.03	1.20	1.33	0.83	0.89	0.94	1.54	1.76	1.75	3.95	3.74	3.75
Magnesium	0.50	0.52	0.53	0.29	0.33	0.36	0.30	0.32	0.33	0.65	0.74	0.74	1.94	2.05	2.00
Iron	1.38	1.43	1.46	0.42	0.45	0.49	0.97	1.02	1.10	1.04	1.09	1.10	1.71	2.22	2.13
Zinc	2.69	2.72	2.75	0.86	0.96	1.03	1.17	1.20	1.26	1.43	1.40	1.41	3.31	2.43	1.04

[a]Numbers in parentheses are sample sizes.

The sample means of INQs of meat (not reported here) for food stamp recipients versus nonrecipients, black versus nonblack, and only female headed versus nononly female headed households have patterns similar to those for educational levels. In terms of fat and saturated fat, households receiving food stamps, blacks, and those that are only female headed consume lower quality commodities than others. In terms of cholesterol, however, this is not true. The amount of nutrient intake can also be detected by combining the INQs with the meat consumption shown in Table 19.1. Nevertheless, the meat consumption patterns shown by the INQs for different household groups may better indicate the quality differences of food consumed.

Regression Results

As the first step in the price-quality analysis, the conditioning diagnostics of the ten INQs plus the intercept are carried out for each of the five meats. To avoid repetition, we only delineate the procedure for the conditioning diagnostics for beef. The same procedure is applied to other meat items.

The condition diagnostic results for an intercept term (v1) and ten INQs (v2-v11) are presented in Table 19.4. Because a scaled condition index above 30 indicates a moderate to a strong collinear relation, there are about seven collinear relations (number of scaled condition indexes larger than 30). Clearly v2 (fat) and v3 (saturated fat) are nearly perfectly collinear. V7 (vitamin-B12) and v4 (cholesterol) also have a relatively large proportion of variance associated with the larger scaled condition indexes. As a first attempt, the first three variables are eliminated. The diagnostic procedure continues for the remaining eight variables (Table 19.5).

There are still four large condition indexes. The five variables of v4 (cholesterol), v5 (niacin), v6 (vitamin-B6), v8 (phosphorus), and v9 (magnesium) are strongly involved as shown by the proportions of variances associated with the largest condition index. Four out of the five are eliminated. Vitamin-B6 is kept because it has a relatively smaller variance proportion associated with the largest condition index. The condition diagnostic results for the remaining four variables are presented in Table 19.6. Now all condition indexes are less than 30 and no further diagnostics are needed. Including these four variables in the price-quality equation of beef should provide precise estimates of price-quality relationships.

After the conditioning diagnostics, the number of INQs left for beef, pork, lunch meat, poultry, and fish are 4, 6, 7, 5, and 11. The numbers indicate that the matrix of INQs of beef is the most ill conditioned while that of fish is the best conditioned. The ill condition of the INQs matrix implies that the nutrients contained in beef are closely correlated. Therefore, we can say that beef is the most homogenous and fish is the most heterogenous commodity.

TABLE 19.4 Scaled Condition Indexes and Variance-Decomposition Proportions (INQs of Beef)

Scaled Condition Index	Proportions of										
	v1[a]	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.001	0.010	0.000	0.001	0.001	0.002	0.001
17	0.001	0.000	0.000	0.000	0.175	0.013	0.016	0.000	0.006	0.001	0.000
26	0.000	0.000	0.000	0.000	0.028	0.189	0.009	0.000	0.001	0.003	0.158
32	0.006	0.001	0.001	0.000	0.138	0.018	0.059	0.033	0.045	0.000	0.007
44	0.006	0.000	0.000	0.026	0.036	0.053	0.001	0.027	0.019	0.421	0.117
54	0.000	0.001	0.000	0.042	0.116	0.155	0.319	0.022	0.055	0.136	0.197
76	0.014	0.002	0.015	0.535	0.141	0.217	0.014	0.008	0.000	0.009	0.442
83	0.181	0.001	0.004	0.001	0.285	0.109	0.046	0.131	0.420	0.367	0.074
139	0.687	0.001	0.028	0.270	0.042	0.230	0.305	0.739	0.404	0.030	0.002
309	0.105	0.993	0.951	0.126	0.039	0.006	0.230	0.038	0.048	0.032	0.001

[a]v1 = constant, v2 = fat, v3 = saturated fat, v4 = cholesterol, v5 = niacin, v6 = vitamin-B6, v7 = vitamin-B12, v8 = phosphorus, v9 = magnesium, v10 = iron, and v11 = zinc.

TABLE 19.5 Scaled Condition Indexes and Variance-Decomposition Proportions (INQs of Beef)

Scaled Condition Index	Proportions of							
	v1[a]	v4	v5	v6	v8	v9	v10	v11
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.016	0.003	0.027	0.044	0.002	0.001	0.002	0.000
19	0.081	0.006	0.247	0.019	0.000	0.018	0.002	0.005
22	0.012	0.000	0.076	0.269	0.002	0.006	0.005	0.228
35	0.003	0.011	0.056	0.096	0.113	0.079	0.112	0.238
38	0.100	0.013	0.104	0.126	0.018	0.043	0.383	0.282
66	0.619	0.504	0.002	0.104	0.031	0.212	0.351	0.235
87	0.168	0.464	0.488	0.342	0.833	0.641	0.145	0.011

[a]v1 = constant, v4 = cholesterol, v5 = niacin, v6 = vitamin-B6, v8 = phosphorus, v9 = magnesium, v10 = iron, and v11 = zinc.

TABLE 19.6 Scaled Condition Indexes and Variance-Decomposition Proportions (INQs of Beef)

Scaled Condition Index	Proportions of			
	v1[a]	v6	v10	v11
1	0.002	0.001	0.000	0.001
9	0.388	0.190	0.005	0.003
17	0.609	0.376	0.035	0.380
28	0.001	0.433	0.960	0.616

[a]v1 = constant, v6 = vitamin-B6, v10 = iron, and v11 = zinc.

Table 19.7 presents the regression results of price-quality functions for the five meats. The inclusions of INQs are based on the diagnostic results. All the five equations include the same set of economic and socio-demographic variables. Statistically, the majority of estimated parameters are significant at the 5 percent level in all the five equations. The R^2's range from 0.20 to 0.33, which are reasonable for an analysis of cross-sectional data. By and large, the significant estimates have expected signs.

TABLE 19.7 Regression Results of Price-Quality Functions

Parameter	Beef (N = 3542)[a]	Pork (N = 2925)	Lunch Meat (N = 2711)	Poultry (N = 3062)	Fish (N = 2205)
Intercept	0.617* (5.70)[b]	1.200* (9.19)	0.818* (6.19)	-0.587* (-4.24)	0.240 (0.72)
Fat	–	–	–	–	0.713* (2.64)
Saturated Fat	–	–	–	–	-0.626 (-1.51)
Cholesterol	–	-0.602* (-6.44)	-0.656* (-18.03)	–	0.178* (7.44)
Niacin	–	–	-0.076 (-1.41)	0.292* (24.21)	-0.031** (-2.27)
Vitamin-B6	1.626* (19.56)	-0.206* (-2.60)	1.059* (12.64)	–	0.068 (1.43)
Vitamin-B12	–	–	–	-0.180* (-12.98)	-0.009* (-4.41)
Phosphorus	–	–	–	–	-0.153* (-2.70)
Magnesium	–	4.219* (14.20)	1.338* (4.80)	–	0.158** (2.57)
Iron	-0.184** (-1.84)	0.613* (3.09)	0.214* (5.08)	0.851* (9.43)	0.188* (4.04)
Zinc	-0.363* (-8.68)	-0.460* (-3.70)	0.048 (0.64)	-0.151* (-2.64)	0.016* (5.14)
Log(FC)	0.248* (10.91)	0.200* (7.45)	0.213* (7.52)	0.157* (5.45)	0.542* (8.95)

(continues)

TABLE 19.7 *(continued)*

Parameter	Beef (N = 3542)[a]	Pork (N = 2925)	Lunch Meat (N = 2711)	Poultry (N = 3062)	Fish (N = 2205)
ED1	-0.047 (-1.16)	-0.120** (-2.52)	-0.150* (-3.14)	-0.038 (-0.76)	-0.0004 (-0.004)
ED2	0.094* (3.25)	0.085** (2.49)	0.086** (2.43)	0.001 (0.01)	0.187** (2.43)
ED3	0.295* (5.39)	0.278* (4.32)	0.133** (2.00)	0.066 (0.99)	0.387* (2.87)
Black	-0.118* (-2.86)	-0.186* (-3.90)	-0.159* (-3.34)	-0.240* (-4.89)	-0.794* (-7.06)
Age	0.002* (2.75)	0.002** (2.26)	0.004* (3.60)	-0.002** (-2.12)	0.003 (1.39)
Food Stamp	-0.109** (-2.14)	-0.080 (-1.34)	-0.033 (-0.56)	-0.043 (-0.68)	-0.190 (-1.37)
Female Headed	0.036 (1.12)	0.055 (1.45)	0.039 (1.00)	0.149* (3.77)	0.057 (0.66)
R^2	0.25	0.20	0.27	0.33	0.22

Note: The superscripts * and ** correspond to the levels of statistical significance of 1 percent and 5 percent, respectively.

[a]N denotes the sample size.

[b]Numbers in parentheses are t-statistics.

The coefficients on the INQ of cholesterol for pork and lunch meat are negative and statistically significant, as expected. The parameters of the fat and cholesterol indexes for fish have unexpected positive signs and are statistically significant. Because the fat index in fish is very low, consumers may not be concerned about the fat content as seriously as in other meat products. The low fat index may mislead consumers' perceptions of the cholesterol content in fish. The signs of the estimated coefficients of other INQs are mixed. If we look at the specific major source of the respective nutrients, a meaningful explanation can be given. For example, if the expensive beef item has a high INQ of vitamin-B6, the positive coefficient of the vitamin-B6 INQ in beef is expected. Similarly, if the cheap (low quality) beef item has a high zinc INQ, the estimated coefficient of the zinc INQ in beef should be negative.

Across the five meats examined in this study, the logged per capita total food cost has a significant and positive coefficient estimate. These results imply that high income households do pay more for a unit of food consumed. Although the higher price may reflect the services purchased, such as packaging and shopping environment, it is more likely that quality, such as boneless, well-trimmed beef, is the major reason for higher prices.

The regression results indicate that the higher the educational level achieved by the household head, the higher is the quality of food consumed. Poultry is an exception with no significant estimates associated with any of the three educational levels. By racial groups, blacks consume cheaper meat than nonblacks, ceteris paribus. Households headed by an elderly person consume higher quality meat except poultry and fish, which have negative and insignificant estimates. Food stamp program participation and household head status do not affect the quality of food consumed as much as other demographic variables. However, households receiving food stamps tend to consume cheaper meat. This pattern may reflect their behavior as low income consumers.

Except for fish, all the price-quality equations do not include the INQ for fat or saturated fat due to collinearity problems. To verify whether the other nutrients included in the price-quality equations can represent the variation of fat or saturated fat, two auxiliary regressions were formed for each meat except fish. The auxiliary regressions are performed by regressing the INQ of fat or saturated fat on the selected INQs for each meat. The regression results are reported in Table 19.8. Almost all the coefficient estimates are statistically significant at the 5 percent level. The R^2's are very high for pork, lunch meat, and poultry. The R^2 for beef is 0.51 although only three INQs are included. These results suggest that the sets of selected INQs are representative of the INQs of fat and saturated fat in these meats.

The explicit relationships between fat and prices of meat are estimated by replacing the set of selected INQs by the INQ of fat or saturated fat in price-quality functions. Because the INQs of fat and saturated fat are highly correlated, only one of them can be used in the regression. Selected regression results are reported in the bottom rows of Table 19.8. The parameters for other economic and demographic variables are consistent with the previous results and, therefore, are not reported. Both INQs of fat and saturated fat are all significantly and negatively related with prices for all four meats. This implies that a higher INQ of fat or saturated fat is associated with lower quality of these food items. Consumers are willing to pay a higher price for less fat and saturated fat content in beef, pork, lunch meat, and poultry.

TABLE 19.8 Results of Auxiliary Regressions and Selected Regression Results of Price-Quality Functions[a]

Item	Beef[b]		Pork		Lunch Meat		Poultry	
	INQ1	INQ2	INQ1	INQ2	INQ1	INQ2	INQ1	INQ2
Auxiliary Regression:								
Intercept	2.991 (211.5)	3.713 (204.4)	3.495 (476.9)	3.851 (374.7)	3.067 (391.3)	3.578 (287.7)	3.270 (274.2)	2.72 (237.8)
Cholesterol	–	–	-0.160 (-17.6)	-0.102 (-8.05)	0.015 (3.58)	-0.158 (-23.8)	–	–
Niacin	–	–	–	–	-0.099 (-16.0)	-0.129 (-13.0)	-0.196 (-115.8)	-0.162 (-99.9)
Vitamin-B6	-0.321 (-17.4)	-0.388 (-16.4)	-0.098 (-12.7)	-0.087 (-7.97)	-0.194 (20.1)	-0.437 (-28.6)	–	–
Vitamin-B12	–	–	–	–	–	–	0.006 (2.96)	0.006 (2.90)
Magnesium	–	–	-0.876 (-30.2)	-1.445 (-35.5)	-0.825 (-25.7)	-0.778 (-15.3)	–	–

Iron	-0.193	-0.283	-0.425	-0.903	0.038	0.087	-0.002	0.044
	(-8.65)	(-9.90)	(-22.1)	(-33.4)	(7.93)	(11.3)	(-0.18)	(3.49)
Zinc	-0.023	-0.040	-0.024	0.148	0.016	0.220	-0.435	-0.372
	(-2.44)	(-3.35)	(-1.96)	(8.74)	(1.82)	(16.3)	(-52.4)	(-46.7)
R^2	0.51	0.53	0.96	0.95	0.87	0.87	0.87	0.82
Price-Quality Function:								
Parameter	-0.802	-0.582	-0.649	-0.535	-1.000	-0.484	-1.514	-1.845
	(-14.0)	(-13.3)	(-16.8)	(-17.3)	(-15.0)	(11.5)	(-31.7)	(-32.5)
R^2	0.14	0.13	0.15	0.15	0.13	0.10	0.30	0.31

[a]The significance levels of parameter estimates are not indicated because all parameters except one in INQ1 of poultry are statistically significant at the 5 percent level. Fish is not included in this table because of its very low fat and saturated fat INQs.

[b]INQ1 and INQ2 are the INQs of fat and saturated fat, respectively. For the auxiliary regression, they are the dependent variables while they are independent variables in the price-quality equations.

Conclusions

This chapter proposed an alternative method to analyze consumer demand for meat. Incorporation of well-defined nutritional quality indexes provides useful insights into nutrition valuation. The results are useful to consumers in making food choices, to health professional and government agencies in initiating consumer education and food assistance programs, and to the meat industry in improving product quality to meet consumers' needs. The proposed methodology can be applied to other food items.

The derived INQs of ten nutrients in five meats show that no meat is good in all nutritional aspects. This finding suggests that the optimal combination of nutrients can only be achieved through a combination of meats. Since "eat a variety of food" is usually the first dietary recommendation suggested by health professionals, a variety of meats may be a part of it. The varying patterns of INQs across different household groups and meat products suggest strong quality variations in meat consumed. The fat and saturated fat consumption of households with a well-educated, nonblack household head are lower than for other households because they consume less meat and the meat they consume has lower INQs of fat and saturated fat.

The conditioning diagnostic results proved that some foods, such as fish, are more heterogenous in nutritional quality than other foods, such as beef. This finding has important implications for applied demand analysis. For cross-sectional studies, the estimated demand parameters will be biased for a heterogeneous commodity if the quality effect is not accounted for.

The regression results indicate that the price of a meat is associated with its nutrition attributes. Higher price may not mean less quantity demanded but higher demand for quality. This is somehow a controversy in traditional demand analysis. The significance and expected signs of the estimates also verify that the procedure used in this study for selecting INQs for price-quality functions is appropriate. Consumers have a negative valuation on fat, saturated fat, and cholesterol in all meat products except fish. The demand for a meat is affected by its fat and saturated fat content.

Notes

1. The comments of Julie A. Caswell and Ping Zhang are much appreciated.

2. The W_{ij} is similar to the percent daily value of nutrients used in the new food labels, which is based on a 2,000 calorie diet.

3. For the strengths and weaknesses of other approaches, the reader is referred to Belsley (1991).

4. The sample statistics of meat consumption for households in the base

educational category are not reported due to space considerations. The patterns for these households are very consistent with the reported three categories.

5. Protein is not included for analysis based on the belief that the American diet is over-nutritious in protein.

6. A food is called a balanced source of saturated and unsaturated fat if it contains a balanced proportion of saturated and unsaturated fats.

7. The INQs for households in the base educational category are not reported due to space considerations. The patterns for these households are very consistent with the reported three categories.

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