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An Econometric Analysis of Consumer Demand for Nutrients in Canada

by

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ABSTRACT

The objectives of this thesis are (1) to determine the shadow prices for protein, fat and cholesterol, (2) to use these implicit prices to estimate the demand for nutrients and (3) to test for the stability of the demand parameters over time. The implicit prices for the nutrients are estimated using the hedonic model. Elasticities are derived from the linear expenditure system using three stage least squares in order to account for the endogeneity of implicit prices and expenditure for nutrients. The econometric results suggest that (1) consumers have been valuing protein positively for the entire period 1960-1987; (2) energy is consistently valued negatively; (3) fat has an ambiguous valuation due to its dual role as a nutrient and a taste enhancer and (4) cholesterol is positively valued up to the late 70's and is negatively valued for the 80's. The cross price elasticities suggest that little substitution takes place among nutrients. Income elasticities indicate that protein, fat and energy are normal goods while cholesterol appears to be an inferior good. Own price elasticities for protein, fat and cholesterol have the expected sign and are very high. Energy has a positive own price elasticity. The hypothesis of stability for nutrient demand parameters was rejected.

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> "To those who are not princes, but who on account of their innumerable good qualities deserve to be; not those who might shower on me rank, honours and riches, but those who, though unable would like to do so. For to judge aright one should esteem men because they are generous, not because they have the power to be generous" Machiavelli (pp 93-94).

Among them is certainly my advisor Dr. Barry Coyle who along with Dr. Louise Arthur and Dr. Wayne Simpson insured that:

> "I have not embellished or crammed this book with rounded periods or big impressive words or with any blandishment or superfluous decoration of the kind which many are in the habit of using to describe or adorn what they have produced for my ambition has been either that nothing should distinguish my book, or that it should find favour solely through the variety of its content and the seriousness of the of the subject matter" Machiavelli (pp 29-30).

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Chapter I

BACKGROUND AND RESEARCH OBJECTIVES

1.1 PROBLEM STATEMENT

Consumer demand theory hinges on one concept and one principle: ordinal utility and its maximization under some resource constraints. Traditionally, utility is assumed to be derived from the consumption of one or multiple goods.

In 1966 K.J. Lancaster levelled serious criticisms against the standard consumer theory. He proposed a new approach to consumer theory with "a model set out as a general replacement of the traditional analysis (which remains as a special case), rather than as a special solution to a special problem. The chief novelty lies in breaking away from the traditional approach that goods are the direct object of utility and instead supposing that it is the properties or characteristics of the goods from which utility derived." (PP. 132-157)

Applied to food demand analysis the theory predicts that consumers are not interested in meats as such but in characteristics such as their nutritional content. This is all the more important given the health awareness of many people. As Zafiriou notes:

> "An increase in the health-consciousness of consumers is another reason given for declining red meat consumption. There has been an increase in the number of Canadians who regularly exercise, a decline in the proportion who smoke and an increase in the popularity of low calories and low fat foods ." (Food market commentary,1985: 20-35).

In the same vein, a survey conducted by Actionable Market Research in 1985 concluded that health is the number one concern among consumers of beef because its fat and cholesterol content are thought to be contributing to coronary disease.

The above thoughts can be generalized to other food commodities and suggest the fundamental idea that the value attached to food products is closely related to their nutritional content (henceforth refered to as characteristics). Economic agents have an intuitive knowledge of this relation. Evidence exists in the literature to the effect that (1) consumers are willing to pay more for food as nutritional value increases (Eastwood et al, 1986) and (2) market researchers, advertisers and manufacturers "also act as though they believe that knowledge (or belief in) of the intrinsic properties of goods is relevant to the way consumers will react towards them." (Lancaster, 1966 pp. 132-157).

At the policy level, the public authority has acknowledged the importance of nutrient data. The extensive use of nutrient data in dietary studies, nutrition education and food policy formulation testify to this fact (Food Market

Commentary, vol3, no4, 1981). The growing relevance of food nutrients in public policy and personal use led Agriculture Canada (1981) to arrange a research contract to (1) evaluate, describe and propose improvements to the data base relating to the nutritional aspects of food prices and food use and (2) include comments on the data relating to nutrient composition, food disappearance, food consumption and food prices. The implicit objective was to design a food basket that would meet the nutritional requirement at minimum cost.

The idea of nutritious food baskets is not recent (L.G. Robbins, Food Market Commentary, 1981). The Montreal Diet Dispensary was the first institution (1953) to build a food basket to assist poor families to select a nutritious diet at minimum cost. Since then, the government has been active in designing food policies based on the nutrient-food-cost relations. In 1973, the Federal government established the Food Price Review Board(FPRB). Its objectives were to monitor rapidly increasing food prices and to determine the effects of inflation on the diet of Canadians. The FPRB commissioned a study with the specific goal of developing a method to determine the cost of feeding Canadians an acceptable and nutritionally adequate diet. The study concluded that most Canadian families were spending more than necessary for a nutritious diet. The FPRB built the retail food at home price index and, 56 of 68 commodities covered by the index were in the nutritious basket recommended by the FPRB. Essentially, this was meant to induce consumers to select food products not for their own sake but for the nutrients they embodied .

On the government's part the desire to link food strategy to nutrition was explicit in a 1979 cabinet discussion paper titled "Integration of nutrition into food strategy". Indeed, the paper recommended that government food policies should reflect good nutrition principles. In 1979, the Anti Inflation Board replaced the FPRB and continued the retail at home price index and the cost of the nutritious diet. These functions were transfered to Agriculture Canada which has since built a data bank on nutrient supply and consumption using the Agriculture Canada nutrient assessment program.

Studies demonstrate that there are compelling reasons for the government to be interested in the nutritional status of its people and for people to care about what they eat. In 1970, Nutrition Canada undertook a nutrition survey to "estimate the prevalence of nutritional diseases and disorders" and "to identify the types of food and estimate the quantity normally ingested". The study concluded that (1) many Canadians were at risk of being ill nourished or were not receiving an adequate diet; (2) prevailing problems were obesity, iron deficiency, low vitamin C intake and a shortage of calcium and vitamin D in the diet. 1613000 adults were grossly obese, 2193000 had high blood cholesterol, 1585000 did not have enough iron and 1823000 were not getting enough calcium.

The important fact here is what the above numbers represent in economic terms. Sabry (1975) quantified the loss attributable to malnutrition and the cost is indeed substantial: $ 916 million for hospitalization, 152 million $ for medical care, $338 million for dental care, $ 48 million due to premature death and $ 1.7 billion for loss in productivity due to absenteeism (school and work) because of nutrition related diseases. The total cost is almost $ 8 billion per year.

Improved health awareness and nutrition education apparently have led consumers to pay increasing attention to the nutritional content of food products. Recent observations suggest that this is the case. Examining the trends in the nutrient composition of the Canadian food supply, Agriculture Canada notes that consumers are increasingly aware of the link between nutritious eating and good health (Robbins and Hunt, Food market commentary, vol17 no3 1985). The concern over fat and cholesterol led them to shift from butter to margarine, to buy leaner meats, poultry and fish and to consume low-fat milk and less eggs. In addition Agriculture Canada (Food Market Commentary, 1987) reports that consumers are "highly influenced by research findings, trade articles and the media reports about food and nutrition and they are willing to modify their diet if they perceive the change to be beneficial". The conclusions of Agriculture Canada are consistent with preliminary findings of a study under way in the University of Guelph on Canadian meat consumption patterns (T.Watts et al, Food Market Commentary vol 10, no2, 1988). In interviews consumers identified meat "with strength and energy, essential for strength and health" (pp 28-35). The pork fat content and the egg cholesterol content were negative factors. Lamb and veal were reported tastier but again their fat content was a concern. The results of the study also suggest that consumers have concerns about livestock husbandry practices and the use of chemicals in meat production and processing, presumably because these factors affect negatively the quality of food products.

The above results from different studies confirm the intuition behind Lancaster's hypothesis that utility is not derived from goods but rather from the characteristics they embody. As is apparent in the preceding pages, the hypothesis is likely to be relevant in the case of food products. The government has attempted to integrate food policies and nutrition, to define welfare assistance on the basis of foods with high nutritional values and to link health to diet through nutrition education programs. As a result, presumably for cost or health reasons consumers pay greater attention to the nutrient characteristics of foods. Sabry (1979) gives the ultimate justification for our study:

> "The consequences of malnutrition are costly in terms of human sufferings medical care and loss of productivity. Intervention programs to alleviate nutrition problems will undoubtedly represent impressive returns in monetary terms as well as in the enhancement of the quality of life in Canadian society.There should be no doubt that nutrition constitutes a vital part of a national food policy" (1979).

This study intends to provide the economic parameters essential to the formulation of a nutrition food policy. The policy maker needs to know the value the consumer attaches to nutrients i.e what nutrients (if any) are valuable and how do prices and income influence this valuation. This is the subject matter of our study.

1.2 OBJECTIVES, SCOPE AND ORGANIZATION

The thesis seeks to determine implicit prices of nutrients (value of the nutrients to consumers) from selected food groups. A natural extension of the thesis is to use these implicit prices to carry out demand analysis for selected nutrients (rather than goods). To achieve these objectives, we specify a nutrient demand system whose explanatory variables are shadow prices derived from a hedonic price model and a nutrient budget. The demand system is derived from the Klein-Rubin utility function.

The hedonic estimates allow the formulation of the characteristics budget constraint which is generally different from the budget constraint in the goods space. From the nutrient demand equations, the nutrients' implicit prices and expenditure elasticities will be computed. As is well known, elasticities are important policy parameters. For example positive income elasticities for nutrients would imply that nutritionally adequate diet could be achieved through income transfers, but if these elasticities are small in magnitude, then food aid would be more effective (Adrian and Raymond 1976). Thus, the interest in demand for nutrients and their economic value is more than a mere intellectual curiosity.

The thesis is organized as follows. Chapter two presents the theoretical framework underlying the study and develops a model specific to the issue under analysis. The model will be built along the lines of Lancaster's new theory of demand. Chapter three reviews the relevant empirical literature. Chapter four describes the nature of the data and the econometric methods of analysis. Chapter five will present and analyze the results and chapter six will summarize the conclusions of the study.

Chapter II

THEORETICAL FRAMEWORK AND MODEL DEVELOPMENT

2.1 THE TRADITIONAL CONSUMER THEORY: FOUNDATIONS

The fundamental entities of economic theory are economic goods, or wants or valuations, and its fundamental relation is that of preference (Northrop 1966, Pg 239). Consumer theory even in its highest refinements is an application of this basic principle.

Assume a consumer can purchase N goods at exogenous prices P=(P1...Pn) from his fixed budget Y. The first postulate of consumer theory is the existence of preferences over bundles of the N goods. The consumer must be able to rank different bundles i.e. to state that he prefers bundle "1" to "2" or that he is indifferent. This essentially implies the existence of a utility function U=U(X) for the consumer, where X=(X1, ..., Xn) denotes the levels of consumption of the N goods (Varian 1983, Deaton and Muellbauer 1980).

It is assumed that the consumer chooses the levels of the N goods in order to obtain the maximum level of utility subject to his budget constraint. More formally, the consumer's Marshallian demands X=Xm(P,Y) solve the following static utility maximization problem:

$$\max \; U(X) \quad = V(P,Y) \qquad (2.1)$$
$$\text{s.t} \; PX=Y$$

where V(P,Y) is the consumer's indirect utility function

i.e V(P,Y) denotes the relation between prices and income

and maximum feasible utility.

Problem 2.1 is formally equivalent to

$$\text{Min } PX \quad = E(P,U^*) \qquad (2.2)$$
$$\text{s.t } U(X)=U^*$$

E(P,U*) is the minimum expenditure required to attain utility U* = V(P,Y) which is the maximum utility attainable at prices P and budget Y. The solution to 2.2 yields the Hicksian consumer demands Xh(P,U*).

The following envelope relations define the Marshallian and Hickisian demands in terms of the indirect utility function and expenditure function

$$Xm(P,Y) = -(\delta V(P,Y)/\delta P)/\delta V(P,Y)/\delta Y \qquad (2.3)$$
$$Xh(P,U^*) = \delta E(P,U^*)/\delta P \qquad (2.4)$$

These are Roy's Theorem and Shephard's Lemma respectively. Comparative static changes in Marshallian and Hicksian demands are related by the following Slutsky equation:

$$[\delta Xm(P,Y)/\delta P]+[\delta Xm(P,Y)/\delta Y]*Xm(P,Y) = \delta\ Xh(P,U*)/\delta P \quad (2.5)$$

where $\delta Xh(P,U*)/\delta P$ is symmetric negative semidefinite (Varian 1983). Thus the effects of change in price Pi on Marshallian demands can be decomposed in terms of a Hicksian substitution effect and a Marshallian income effect.

This core theory will become important later because once it is accepted that Lancaster's assumptions hold and that characteristics can be separated from goods and treated as products themselves, the demand for characteristics can be carried out in the framework summarized above.

2.2 LANCASTER'S NEW THEORY OF DEMAND

In his "A new approach to consumer theory", Lancaster (1966) departed significantly from the standard theory presented above. The novelty of his approach "lies in breaking away from the traditional approach that goods are the direct objects of utility and instead supposing that it is the properties of or characteristics of the goods from which utility is derived" (Lancaster, 1966, pp132-57).

The relation of preference ranks characteristics and goods are ranked indirectly through their endowments of characteristics. A major difficulty at this point lies in whether from the optimal choice of characteristics it is possible to recover the goods which correspond exactly to those characteristics. The question is not a trivial one since goods and not characteristics are sold in the market place. On the other hand, since consumers buy goods but think of them as collections of characteristics, there exists an implicit market for characteristics and our analysis is precisely the consumer behavior in that market (Rosen 1974). An interesting issue is again how much the characteristics market reveals about the explicit market i.e. the goods market. This issue can be settled only if the transformation from the characteristics space to the goods space is known or if the characteristics embodied in the goods have an explicit market.

Consider an economy with n commodities and let $X=(X1, \ldots, Xn)$ be the commodity vector. Lancaster regards X as a consumption activity to which a scalar can be associated. If Yk is the level of activity k ,then

$$Xj=\Sigma ajkyk$$

or in matrix form

$$X=AY \qquad (2.6)$$

Here ajk is the amount of good Xj used per unit of consumption activity k. The summation over all consumption activities gives the total level of Xj. It is assumed that (1) is linear and objective, i.e, independent of consumer valuations. Goods have intrinsic properties (characteristics) accepted as a fact independently of the liking of any single economic agent. For example in 4grams of chopped parsley, there are 5mg of calcium, 2mg of sodium, 4mg of vitamin C, etc. Any disagreement can be settled on objective grounds given the state of technology.

Let $Zi=(zi1, \ldots, zin)$ be the vector of objective intrinsic characteristics contained in one unit of product i. Further, accept that the elements of X share the same generic properties in Z and that the difference in products is only in the amount of different characteristics per unit. The total amount of characteristic j from all products (for example total protein derived from the consumption of all food products) can be written as:

$$Zj = \Sigma zijXi$$

or in matrix form

$$Z = zX \qquad (2.7)$$

2.7 states that the total amount of characteristic j is equal to the yield per unit times the quantities of different food products consumed. Equation 2.7 is an objective relation and is assumed to be linear.

In what follows, we have in mind a consumer whose objective is to maintain good health through a proper diet and who chooses food products because of their nutrients. This extreme version of health awareness is probably too stringent. Actually, we can weaken the assumption and accept that they may simultaneously choose on other grounds such as flavors and ease of cooking. This will not modify the line of analysis because (as we will show) the budget can be decomposed into a nutrient and a nonnutrient components.

Preferences are expressed in the nutrients (characteristics) space. There could be doubt as to whether the consumer has the information to answer the 'what-how much nutrients in which products' question. This strong condition can be modified, and we would simply require the consumer to be health aware and to use information about the content of certain nutrients in certain foods.

Under the above conditions Lancaster's theory leads to the following consumer program:

$$\text{Max } U(Z) \quad (2.8a)$$

$$\text{s.t } Z=zX \quad (2.8b)$$

$$PX=Y \quad (2.8c)$$

Two major contributions are attributed to Lancaster's model. One is the existence of an objective efficiency frontier and the other is the ability of the model to discriminate between the objective efficiency substitution effect and the subjective private substitution effect (an elegant exposition of these effects can be found in Ladd 1983).

As noted by Reuven Hendler (1975), the program (2.8a)-(2.8c) has 3 built-in assumptions crucial to its claim of generality: the linear technology (2.8b), the irrelevance in the utility function of the distribution of characteristics among products (2.8a) and the nonnegative marginal impact of characteristics on utility. It has been shown that Lancaster's analysis breaks down if the above assumptions are violated (Lucas 1975, Hendler 1975). Thus it is important to ask whether these assumptions will hold in our case.

The linearity assumption means that a 10% increase in all X will induce a 10% increase in Z e.g, if one doubles his meat ration, his protein intake from meat will double. This assumption should hold. The independence of the utility function from the distribution of characteristics among products means that the protein from cereal is valued the same as the protein from beef or poultry. This is not strictly correct. For example, there is the issue of complete protein and useable calcium. In contrast to meat protein, protein from cereal must be used in combination with other sources for amino acids. The two proteins are in effect different products. Nevertheless it is a reasonable approximation for our empirical purposes to assume that these two proteins are identical. The third requirement of nonnegativity of marginal utilities of characteristics will hold generally over the range of observations. Thus the 3 assumptions (linearity, non-negativity and independence) appear generally to be fulfilled in the context of food commodities.

In the consumer program (2.8b) $Z=zX$ is an identity. The total nutrient Z_i is the sum of the different portions of nutrient i that come from different food products as determined by supply. We will argue later that Z is produced by the household-producer-consumer and is not a constraint at the second stage of the household problem of utility maximization from the nonmarket goods Z. $Z=zX$ can be viewed as a production function at the household level. The budget constraint is given by (2.8c). The equality in (2.8c) is simply the reflection of the local nonsatiation assumption.

The consumer program can also be written as:

$$\text{Max } U=U(Z) \qquad (2.9a)$$

$$\text{s.t } PX=Y \qquad (2.9b)$$

$$Z=zX$$

Note that the utility function is in terms of characteristics and the budget constraint is in the goods space. Consistency requires that the utility function and the budget constraint be in the same space. We can proceed in two ways. The first approach, which crucially depends on the structure of the z matrix, would be to recover the goods matrix given the arguments of the utility function in 2.9a. The question really is whether, given the vector of characteristics, there exists a unique transformation to recover unambiguously the corresponding vector of goods. The second approach, which will be adopted in this study, is to transform the budget bringing it in the characteristic space. Behrman and Deolalikar (1987) have estimated demand equations for nutrients using the regular observed product prices and expenditures and then derived the price and income elasticities. As will be shown later this practice corresponds to the estimation of the reduced form nutrient demand equations and is often recommended when the household technology is non-constant returns to scale and/or exhibits jointness in production. This point will be developed when we discuss the endogeneity of implicit prices.

Before we proceed, let's indicate that the restrictions imposed by the three assumptions can be overcome in a way suggested by Ladd and Zober (1977). They take utility to be derived not from the characteristics but rather from the services S which in turn depend on the characteristics:

$$S = s(Z) \qquad (2.10a)$$

$$tij = f(X, zij) \qquad (2.10b)$$

$$U = (S) \qquad (2.10c)$$

and 2.10c is maximized subject to a properly transformed budget constraint. This program is more complex as we must first go from goods to characteristics and then to services.

In the following analysis, we assume that it is possible to separate the different nutrients contained in food products so that we can consider Z as a vector of characteristics over which complete, reflexive, transitive , continuous and locally nonsatiated preferences are exercised, or equivalently that a well behaved utility function exists.

If utility is defined in the nutrients space, we need to find the shadow prices of those nutrients since they are not generally traded in explicit markets. It is interesting to note that an approximation to the nutrients market may exist: in health food stores, different vitamins, minerals and other nutrients are purchased directly. In this market, the consumer program 2.9a-2.9b becomes:

$$\text{Max } U(Z) \qquad (2.11a)$$

$$\text{s.t} \quad RZ=Y \qquad (2.11b)$$

In (2.11a)-(2.11b), the characteristics Z are products similar to those that could be extracted from food products, and prices R are observed prices rather than shadow prices. Actually, implicit prices obtained from the hedonic model are the proxies for these observed prices R. If these were available there would be no justification for the hedonic price model. (2.11a)-(2.11b) is simpler than (2.9a)-(2.9b) because no transformation is needed from X to Z, and the budget constraint is already in the characteristics space. In order to implement this model, all that needs to be done is to collect data on Z and the corresponding price vector R. (2.11a)-(2.11b) represent a consumer who has singled himself out as health oriented and behaves in the way we have described. 2.9a-2.9b is meant to be an approximation of (2.11a)-(2.11b).

Alternatively, the Z can be derived through the transformation of X into Z and the utility can be maximized under the budget constraint RZ=Y where R are the observed per unit price of nutrients. This specification avoids a problem ordinarily encountered in hedonic price models, that is, the interpretation of the intercept.

We now turn to the transformation of the budget constraint from the goods space to the characteristics space, and we will derive the shadow prices which show the implicit value the consumer attaches to different nutrients. An interesting question is whether the observed price vector R and the computed shadow prices are different. Of course the question reduces to whether the implicit market with computed arguments [Z,β] accurately represents the explicit market where [Z,R] are observed. Expressing 2.9a-2.9b in Lagrange form

$$\text{Max} \quad L = U(Z(X))-\lambda(PX-Y) \qquad (2.12)$$

implies the first order condition

$$\frac{\delta L}{\delta Xi} = \Sigma \frac{\delta U \; \delta Zj}{\delta Zj \; \delta Xi} -\lambda Pi = 0 \qquad (2.13)$$

$$PX-Y = 0$$

where $\lambda = \delta U/\delta Y$ i.e themarginal utility of income.
(2.13) can rewritten as

$$\frac{\delta L}{\delta Xi} = \Sigma[(\delta U/\ \delta Zj)*(\delta Zj/\delta Xi)]\_[(\delta U/\delta Y)*P] = 0 \quad (2.13)$$

which implies that

$$Pi = \Sigma \frac{\delta Zj}{\delta\ Xi} * \frac{\delta U/\delta Zj}{\delta U/\delta Y} \quad (2.14)$$

The shadow price or willingness to pay for an additional unit of characteristic j can be defined as:

$$\frac{\delta U/\delta Zj}{\delta U/\delta Y} = \quad = \beta j$$

The terms shadow price, imputed price and implicit price are used interchangeably and give the implicit valuation of characteristics. If the characteristic j was on the shelves the consumer would be willing to pay βj. Rewriting equation (2.14) in familiar terms gives:

$$Pi = \Sigma\ zij\ \beta j \qquad (2.15)$$

(2.15) is the hedonic price equation and clearly indicates that the price of each commodity is the sum of the implicit prices of different characteristics weighted by the per unit endowments in characteristics.

Let it be clear at the outset that (2.15) is not a price determination equation but rather a price decomposition technique. One gets easily confused when he attempts to interpret Pi(z) as a price. A more suggestive interpretation is to think of transaction in products as equivalent to tied sales (products are seen as bundles of characteristics) and Pi(z) as an expenditure on one unit of a product. For example spinach can be considered as a collection of characteristics. The consumer then is allocating the budget P over the different components of the spinach. Obviously this is not a price determination process. It is important to indicate how this process takes place in the characteristics space and in this we will follow Sherwin Rosen's explanation.

Consumers, in their optimization behavior have a value function i.e willingness to pay for a given product. At fixed income and utility, let it be $\phi(Z,U,Y)$. But in the market place, they face a price P which is the minimum they must pay. Utility is maximized when the market price and the bid function (the value function) are equal i.e $\phi(Z,U,Y)=P(Z)$. On the production side, let a firm have an offer function (the price the firm is willing to accept) $\phi(Z,\pi, \beta)$ at given profit π and optimal production given by β. In the market, the maximum price the firm can get is P(Z) so that the firm will be at its optimum when $P(Z)=\phi(\pi,\beta,Z)$. The equilibrium will be achieved once consumers' value functions are equal to producers' value function and this will determine the market price P(Z). At equilibrium the vector [U,Y, β,π] is determined and the price P(Z) can be seen as an expenditure on characteristics or as the producer's revenue from the characteristics. Note that $\delta\ \phi(Z\ \pi,\ \beta)/\delta\ Zi$ is the marginal supply price for attribute i. $\delta(Z,U,Y)/\delta Zi$ is the marginal consumer valuation of characteristic i.

At equilibrium these are both equal to $\delta P(Z)/\delta Zi$ which measures the implicit prices of characteristics. The fundamental point here is that the price is determined by utility maximizing consumers and profit maximizing producers. Typically, $\phi(U,Y,Z)$ and $\phi(Z,\beta,\pi)$ are unobserved and consequently implicit prices of the characteristics are also unobserved.

The key question is how to recover those implicit prices if the objective is to analyze the demand and supply of characteristics. The supply and demand equations can be written as respectively:

$$\frac{\delta P(Z)}{\delta Zi} = \frac{\delta\ \phi(Z,\ \pi,\ \beta)}{\delta\ Zi} = f(Z,\Delta,\ P(Z))$$

$$\frac{\delta P(Z)}{\delta Zi} = \frac{\delta(Z,U,Y)}{\delta Zi} = f(Z,Y,\xi\ ,P(Z))$$

where Δ, ξ are vectors of producer and consumer characteristics respectively. We know that under equilibrium conditions the observed price is the outcome of supply and demand interaction. The hedonic model simply decomposes this expenditure on one unit of product into expenditure on individual characteristics. Thus the hedonic model is not meant to explain price formation.

In the case of food products, it is possible to derive implicit prices exactly. Consider the case with three products (chicken, beef and pork). Assume further that they contain three nutrients (protein, fat and vitamins). Then the problem of implicit prices can be formulated in the following terms:

$$P1 = z11\beta1 + z21\beta2 + z31\beta3$$

$$P2 = z12\beta1 + z22\beta2 + z32\beta3$$

$$P3 = z13\beta1 + z23\beta2 + z33\beta3$$

In the above system P and zij are known and we have therefore a system of simultaneous equations which can be solved for the β vector. The underlying assumption here is that if the same characteristic is present in 3 different products, the consumer will be consistent and value it at the same implicit price irrespective of product. It is thus possible to derive the implicit prices exactly without any knowledge of how and where they are determined and without any stochastic terms provided the number of characteristics is less than or equal to the number of products.

For the purposes of econometric estimation the hedonic price equation 2.15 can be specified in linear form as:

$$Pi = \alpha0 + \Sigma\ xij\ \beta j + \mu \quad (2.16)$$

If the implicit prices are constant,this simple linear functional form is acceptable. In general implicit prices are a complex nonlinear function of goods prices and income: $\beta j=((\delta U(Z*)/\delta Zj)/\delta U(P,Y)/\delta Y)) = f(P,Y)$ assuming $Z*=Z(P,Y)$. If the hedonic equations are estimated for a cross section of goods at one point in time, then (P,Y) are invariant over the data set. In turn, implicit prices can be treated as constant coefficients β to be estimated as above in (2.16). This is the approach that will be adopted in this study. The question of functional forms for hedonic equations has been considered in more detail by Larry Jones (1988). He demonstrates in the case of competitive consumers that (1) equilibrium prices can be linearly decomposed if all individuals have the same homothetic utility function over characteristics and (2) prices are a convex function of characteristics. Convexity implies that implicit prices must be a decreasing function of characteristics and consequently the second derivatives of P with respect to xij must be negative.

If the implicit prices can be treated as constant and other characteristics such as taste, odor and ease of cooking are irrelevant to the consumer in his choices of food products, the intercept $\alpha 0$ in (2.16) should equal zero. Otherwise $\alpha 0$ should be positive and corresponds roughly to expenditure on non nutrient characteristics. Provided that the covariance between nutrient and non nutrient characteristics over food products is small, omission of non nutrient characteristics from (2.16) does not seriously bias estimators β of implicit prices.

Consumers may exercise preferences over the entire range of nutrients; but it is more likely that consumers care only about a subset of nutrients on which most of them are informed in terms of the potential harm or contribution to their health. As is well known, people are more concerned and more informed about fat, protein, cholesterol, calcium and sodium content than about niacin or riboflavin or potassium. Therefore the analysis can be reduced to this subset of known nutrients. It is important to note that the all-nutrients approach and subset nutrient approach are nested. The subset nutrient approach is easily obtained by imposing certain zero restrictions on the all nutrient approach. From this perspective, empirical studies (Silberberg 1985, Behrman and Deolalikar 1987) impose some useful qualifications.

A study on Kenya reveals that "a strong demand for tasty and palatable foodstuffs as opposed to calories per se displays itself at low household incomes". On the other hand for health oriented consumers, "as income increases, consumers will defer relatively more towards the pleasurable aspects of eating and relatively less towards the production of nourishment" (Silberberg, 1985). In the first case the behavior is explained by a lack of nutrition education which leads people to confuse the pleasurable aspects of food and its nutritional value. The second empirical result simply suggests the existence of an income level beyond which the relevant arguments in the choice model are nutrients and taste variables. The nutrient budget will tend to stabilize, while the tastes budget could be very unstable but will normally be increasing overtime.

The hedonic estimates derive their interest in that they are used to construct the budget constraint in the characteristics space and they indicate the willingness to pay by consumers. Consider the budget constraint. In the goods space we have PX=Y 2.8c. One can go in the characteristics space by using equation 2.8b, Z=BX. However there may not be a one-to-one relationship between goods and characteristics so that we cannot solve Z = BX for $X=ZB^{-1}$ where B^{-1} is the inverse of B. As we are not interested in recovering the goods space, we substitute the hedonic price equation in the goods budget constraint.

$$\Sigma(\alpha 0 + \Sigma zij\beta j + \mu)Xi = Y \qquad (2.17)$$

$$\Sigma\alpha 0Xi + \Sigma\Sigma zij\beta jXi + \Sigma\mu Xi = Y \qquad (2.18)$$

Noting that ΣxijXi=Zj is the total level of nutrient j from all products, 12.18b can be rewritten as :

$$\Sigma Xi(\alpha 0 + \mu i) + \Sigma\beta jZj = Y \qquad (2.19)$$

In practice the hedonic price model is estimated first, and this has the effect of eliminating the error term from the budget constraint . (2.19) becomes :

$$\Sigma X_i a_0 + \Sigma b_j Z_j = Y \qquad (2.20)$$

where $[a_0, b_j]$ is the estimated version of $[\alpha_0, \beta_j]$

The a priori expectation was that the expenditure on nutrient characteristics would exhaust the income Y. The presence of a non zero term $\Sigma a_o X_i$ indicates that this is not the case. This is an important difference between the goods space and the characteristics space considering that most empirical studies have reported an a_0 statistically significant from zero. Observe that if the hedonic model is not linear, the prices of characteristics are not constant but vary with z_{ij}. With semilog and double log functional forms for example, the price is an increasing function of characteristics (Triplett 1975) which is contrary to the predictions of the standard theory. Incidentally the semilog functional forms provide the best fit but the interpretation of the results is counter intuitive. This is because (as we discussed earlier) the hedonic equation is not a model of price determination.

The understanding of the nature of the characteristics budget constraint requires a proper interpretation of a_0 because only then can we see the meaning of $\Sigma a_0 X_i$. As b_j are known to be the implicit prices of characteristics $\Sigma bjZj$, is the income that is in effect allocated to nutrient characteristics. Generally, a0 is interpreted as the price of the omitted characteristics. In the example of Kenya mentioned earlier it appears that $\Sigma Xia0 > \Sigma bjZj$ i.e. the nutrient neutral budget exceeds the nutrient centered budget. In this study, we interpret a0 as the value of unmeasured characteristics of food to the consumer (color, tastiness, ease of cooking, social status, niacin ..etc).

The real budget constraint in the demand analysis for nutrients is therefore not Y but rather:

$$Yn^* = Y - \Sigma a0Xi = \Sigma \beta j \; Xj \qquad (2.21)$$

The above analysis allows us to write the nutrient selection problem as:

$$\text{Max} \quad U = u(Z1 \; Z2 \; Z3 \; \ldots \; Zj \; \ldots \; Zn) \quad (2.22a)$$

$$\text{s.t} \; \Sigma bjZj = Yn^* = Y - \Sigma a0Xi \qquad (2.22b)$$

assuming that the consumer's utility function $U(Z,W)$ is weakly separable in nutrients Z and non nutrient characteristics W i.e. $U(Z,W) = u(U(Z), V(w))$. Given weak separability and implicit prices b equal to equilibrium shadow prices, problem (2.22) does not misrepresent the consumer's choice of nutrients.

2.3 ON THE ENDOGENEITY OF IMPLICIT PRICES

Earlier we stated that the shadow prices or implicit prices of nutrients are endogenous to the consumer. Here we point out that this statement is true even if agricultural product prices are exogenous to the consumer sector. This endogeneity of implicit prices follows from the simple fact that nutrients are obtained as joint products from agricultural commodities, i.e. each commodity purchased contains multilpe nutrients. The fundamental point is that the household is simultaneously a consumer and a producer. As a producer, he buys market inputs (food products) and he combines them with his labor or hired labor and capital to produce nutrients (nonmarket goods) at minimum cost. As a consumer, he maximizes utility from the nonmarket goods subject to the budget constraint which is taken to be the minimum cost from the first stage. More formally, the household production problem is :

$$\text{Min } C = PX+wL = C(P,w,Z,K) \qquad (2.23)$$
$$\text{s.t } F(X,K) = Z$$

PX is the cost of market inputs, L is the amount of labor, w is the wage or opportunity cost of labor, Z is the production level of nutrients and K is the amount of household capital.

The minimum cost can be written as C(P,w,Z,k). Applying the envelope theorem with respect to Z gives

$\delta C(.)/\delta Zi=\beta i(P,w,Z,k)$. As a matter of simplicity assume that labor and capital are unimportant. This is not unrealistic since many food products can be eaten raw. Then $\beta i=\beta i((P,Z)$ and it becomes obvious that the shadow prices generally depend on Z. Furthermore, if $Z*=Z(P,Y)$ solves the global maximization problem (2.9), then Z* also solves the following utility maximization problem :

$$\text{Max} \quad U(Z) = V(\beta*,Z) \qquad (2.24)$$
$$\text{s.t} \ \beta*(P,Z)Z=Y$$

Here implicit prices β are fixed at the equilibrium levels $\beta*=\beta(P,Z)$ and we assume a constant returns to scale technology.

The assumption of constant returns to scale is critical to this formulation of the budget constraint. $C(P,Z) = \Sigma(\delta C(.)/\delta Zi)Zi = \Sigma\beta i(P,Z)Zi$. This follows from Euler's theorem, the constant returns to scale (CRTS) assumption and the application of the envelope theorem. Assuming that the food budget constraint PX< or =Y is binding (nonsatiation) and nutrients Z are the complete set of characteristics for food, it follows that Y=C(P,Z). This establishes the budget constraint in (2.24). Moreover it is reasonable to assume constant returns to scale in the production of nutrient characteristics from purchased agricultural goods i.e. Z=zX where z is a matrix of fixed input output coefficients (element zij is the amount of nutrient j per unit of purchased commodity i).

On the other hand the cost function C(P,Z) is not disjoint in nutrients Z. This follows from the fact that the matrix z of input output coefficients is not diagonal i.e. the transformation function Z=zX is not disjoint in outputs Z (each purchased commodity generally yields multiple nutrients) (Hall, 1973). Jointness of the cost function implies that $\delta S\&2C(P,Z)/\delta Zi\delta Zj\#0$ i.e $\delta\beta i/\delta Zj\#0$. Since implicit prices β vary with the levels of nutrients Z, these implicit prices are endogenous to the consumer even if goods prices P are exogenous.

Pollak and Wachter (1975) first noted that implicit prices were endogenous to the consumer if the household transformation function exhibited either non constant returns to scale or joint production of characteristics. They conluded that, when implicit prices are endogenous to the consumer, they have no explanatory power as independent variables in the household and production model. This greatly complicates the analysis of household and production models. To see this consider consider the example given by Pollak and Wachter (1975, P.265):

> "Consider two households with identical technologies who face the same goods prices and have equal incomes. These two households have the same cost functions and the same feasible set in the commodity space. If the technology exhibits joint production, then the frontier of the feasible set is nonlinear and commodity (non market goods) prices vary with the commodity bundle chosen. Households with different tastes will select different commodity bundles, and, since the frontier is nonlinear, the commodity bundles they select will imply different commodity prices. The unwary economist might attribute the differences inthe consumption

> patterns of our two households to these differences in commodity prices, but such an interpretation would be highly misleading; the differences in commodity prices are a reflection of differences in tastes, not of differences in opportunities."

Nevertheless it is clear that the consumer's maximization problem (2.9)

$$\begin{aligned} &\text{Max } U(Z) \\ &\text{s.t } Z=zX \\ &\quad\;\; PX=Y \end{aligned}$$

does imply that the consumer in effect solves the cost minimization problem (2.23) and the maximization problem (2.24). The endogeneity of implicit prices β does not alter this point: instead endogeneity implies that (2.23)-(2.24) cannot be viewed as a two stage decomposition of the global problem (2.9) snce $\beta*$ in (2.24) depends upon the solution $Z*$ to (2.9). Given that $\beta*$ is evaluated at the global equilibrium level $\beta(P,Z*)$, the utility maximization problem in the Z space has standard neoclassical properties. In other words, the corresponding indirect utility function $V(\beta*,Y)$ for (2.24) is homogeneous of degree zero in its argument, increasing in Y decreasing in $\beta*$, quasi-convex in $(\beta*,Y)$ and satisfies Roy's theorem.

Thus, in spite of the endogeneity of implicit nutrient prices to the consumer, we can still define hedonic price equations (2.16) and nutrient demand equations conditional on implicit prices. Furthermore it has been shown that the corresponding system of econometric equations is identified

(Barnett 1977). As the following chapter reveals, applied studies seem to have ignored this endogeneity of implicit prices.

Chapter III

A CURSORY REVIEW OF EMPIRICAL FINDINGS

Waugh (1928) provided the first study in the hedonic field. He found a distinct tendency for market prices of many commodities to vary with certain characteristics that the consumer identified with quality. For example, he estimated that each additional inch of green color per stalk added 34.45 cents to the price of one dozen standard bunches of asparagus. More recently, in the case of beef, the implicit price of protein was estimated as 1.66 cents (Ladd and Suvannut 1985).

Studying the wheat market Veeman (1987) estimated that a 1% increase in protein content in the 70's would have resulted in a $ 3.34 premium per tone which was consistent with the market of the time. King (1976) applied Lancaster's approach to demand for housing and found that fireplaces were worth about $1000 which approximated the construction cost in the explicit market. The correspondence between implicit prices and real prices is of vital importance as it justifies the use of the hedonic approach for pricing purposes. It also legitimizes the use of implicit prices in studies of consumer behavior. Further, it is a reply to the skepticism that one may interpret hedonic results as measures of prices but that does not make them so ; or that one must provide "the most convincing evidence that hedonic estimates represent economic reality and not just some statistical accident" (Jack E.Triplett,1975).

The point need not be belabored. Theoretical work (Jones 1988, Lucas 1975, Rosen 1974) and empirical studies in various fields such as food, housing and transportation have demonstrated the soundness of hedonic prices as operational economic concepts. These hedonic prices are to the characteristics space what prices are to the goods space in the formulation of the budget constraint.

Surprisingly, very few studies have dealt with the demand for characteristics in a utility maximizing or other demand system framework. King (1975) estimated the demand for housing characteristics using the Rotterdam model. Eastwood et al (1986) estimated demand for nutrients in the U.S. but their model was an ad hoc one: nutrients were specified to depend on implicit prices in a linear fashion but nothing was said about the nature of consumer preferences (over the characteristics space) which are supposed to yield the equations for the nutrients. Moreover, they specified demand equations for 7 nutrients without providing an answer to the questions whether (1) the consumer is aware of the nutrients (2) the consumer knows the food products which have a comparative advantage in providing those nutrients and (3) the nutrients are the consumer's explicit choice variables. In fact the number of nutrients was reduced because of multicollinearity considerations rather than being based upon an explicit discussion of consumer attitudes towards nutrients. This criticism equally applies to the Knudsen and Scandizzo (1982) study on demand for calories in developing countries. They estimate the shadow price for calories. They then use this implicit price and food expenditure to estimate own implicit price and income elasticities. But it is not clear whether consumers in developing countries choose food products on nutritional grounds or for other reasons. Without an answer to this question, the economic interpretation of the estimates is rather ambiguous Another example of this can be found in Behrman and Deolalikar (1987) in the section on data. Nevertheless, Eastwood et al (1986) reach an interesting and expected conclusion: own price elasticities of the nutrients suggest that the demand for nutrients is inelastic and the cross-price elasticities are very low or insignificant, i.e very little substitution takes place across nutrients. It is therefore reasonable to postulate an additive utility function in the nutrients space.

Finally, there are substantial differences between the above studies and this thesis. Consequently, it might be worthwhile to contrast the approaches between this study and the rest. The main difference is methodological. In this thesis we select nutrients known to the consumer and consequently we limit ourselves to products that are bought or avoided because of some of their nutrients. This question has generally been overlooked or assumed away and yet it is only when we know that preferences are exercised that we can study the demand for nutrients using the standard demand theory. Also it seems too strong an assumption to require the consumer to know all the nutrients. This question of existence of preferences in the nutrients space is not trivial. It is only when these preferences are present that (1) implicit prices and the implicit nutrient budget do make economic sense as explanatory variables and (2) that nutrients elasticities are economically meaningful. Indeed assume that the consumer does not care about nutrients then computing implicit prices or price and income nutrients elasticities with respect to implicit prices simply gives misleading results. The key point that should be understood is that in no way do preferences in the food products space imply preferences over the nutrients space as is customarily assumed in the literature.

Another departure is the explicit recognition that implicit prices are generally endogenous and that OLS or SUR methods may not be appropriate econometric methods to use. Also, as indicated in the previous chapters, many studies have estimated linear relationships without regard to the theoretical but reasonable restrictions implied by demand theory. By using a utility-based demand model we assure that the estimated demand equations have the minimum restrictions which precisely make them interpretable in the framework of demand theory. But even in this study, there is a degree of arbitrariness (in the choice of those nutrients) which we reduced by using the prior information available to us.

Chapter IV

EMPIRICAL IMPLEMENTATION

4.1 DATA DESCRIPTION AND LIMITATION

So far nothing has been said with regard to the question of nutrients and products (which nutrients from which products) we intend to use to evaluate consumer behavior in the nutrients space. The hints given earlier are suggestive of the direction we will follow.

As all nutrients are not equally well known and the consumer pays attention to only a few of them and probably ignores or is unaware of the rest, the choice of the nutrients the consumer is interested in becomes an important matter if we want to get economically meaningful estimates.

There is no rigorous guide to this decision. Here we adopt a simple rule: the arguments of the utility function will be those nutrients on which there is a reasonable agreement that most consumers are informed and concerned.This rule is loose and largely intuitive, but it is about the best we can do and is certainly an improvement over what has been done so far. It is worthwhile repeating here that we rely on our prior information to select a subset of nutrients that is relevant to our model. The alternatives to this method are less satisfactory: the high multicollinearity within a complete set of nutrients implies that it is difficult to select the relevant nutrients on purely statistical grounds. Based on the above rule, it is possible to enunciate possible choices.

There is a distinct tendency among consumers to react to negative characteristics because they are associated with known hazards such as coronary diseases and obesity. On this ground, the arguments of the utility function must include nutrients such as fat and cholesterol. For positively perceived nutrients one might think of protein, vitamins and energy. In this case, the Z vector includes fat, cholesterol, protein, vitamin, energy.

Similarly, one can start from the idea that the consumers' knowledge is aggregate, that is, he does not know the different vitamins, minerals, fats and other nutrients; but he considers it important to eat certain products to get vitamins or minerals. Equally, he makes it a point to avoid (or to be cautious about) certain products because of fat and cholesterol: it is not uncommon to hear people say that one must eat fruits and vegetables and avoid eggs to get vitamins and to minimize cholesterol intake. The choice in the nutrients space can be rationalized on this basis.

To implement empirically this choice, the need arises to define meaningful aggregates that correspond best to the information possessed by consumers. The vector Z would then include the above groups or any others Where it is suspected that the consumer has specific knowledge on certain nutrients and aggregate on others; the previous two cases can be combined.

There is a more fruitful approach that we adopt in this study: the investigation of consumer behavior starts from commodities commonly known as sources of certain nutrients so that when the consumer chooses these commodities, he is in effect selecting nutrients associated with those products i.e the goods themselves are merely a medium. If these products are known to exist, they constitute the appropriate domain to analyze consumer behavior in the characteristics space.

There seems to be a consensus that demand for meats in Canada is heavily dependent upon certain of their characteristics (fat, protein and energy). The concern about cholesterol and other fats is probaly the most widespread and these nutrients are generally identified with eggs, meats and the fat and oil commodity group.

For our empirical analysis, we postulate that in this segment of the food market - namely the meat market, the egg market and the fats and oil market - the consumer buys products in order to get these nutrients. As said earlier, it is implausible to argue that this explicit choice concerns all nutrients. Only a subset is relevant and we take it to contain fat, cholesterol, protein, energy.

Besides the relevant products and nutrients issue there is a temporal dimension to the problem: when did the consumer become interested in nutrients? There is general agreement that awareness and concern about fat and cholesterol increased substantially in the early 70's. This fact must be taken into account in the analysis. We will therefore estimate two related models. The first simply assumes that in the meats-eggs-fats and oil market the consumer has always behaved in the nutrient space and there has been no structural shift in the parameters characterizing the consumer behavior. The other model accepts that the consumer's awareness about nutrients began in the 70's. Prior to this period, the consumer is assumed to have chosen products without a knowledge of the importance of their nutrient composition. Naturally, it is of interest to test whether there has been a structural change in the parameters between the two periods and with respect to different nutrients.

The implementation of the model(s) requires information on the vector of relevant nutrients (characteristics) Z. These are calculated by Agriculture Canada as $Z=zX$, where z is the matrix of technical coefficients (nutrient levels per unit of agricultural goods) and X is the vector of consumption levels for agricultural goods. The content of the following nutrients was calculated for every commodity: energy, protein, carbohydrates, saturated fat, polyunsaturated fat, cholesterol, calcium, iron, sodium, potassium, thiamin,vitamin A, riboflavin, niacin, folate, vitamin C and dietary fibre and fat.

The nutritional data has some important limitations that must be understood for a proper interpretation of demand results. These limitations are extensively described by Agriculture Canada (1981). Here, we simply present a summary of those limitations.

The first limitation is that food disappearance is calculated at the retail level and is not adjusted for losses and waste occuring at stores, homes and restaurants. This practice results in an overestimation of the amount of nutrients consumed.

Agriculture Canada also indicates that food disappearance data for some commercially processed food is not available and this tends to underestimate the nutrient intake of Canadians. Cake mixes, ready to serve meals and fruit-drink cristals are examples of omitted products. There is no allowance made for those food products that are not exchanged in the market place.

Another serious limitation is in the per unit nutrients values (the z matrix): these technical coefficients rely substantially on American data. The problem of applying American data to the Canadian situation is that nutrient content of plant food depends on the varieties, soil type, fertilizers used, length of the day and light exposure. All of these vary across countries and regions. For animal products there is not much variation except for iron and vitamin A which depend on the animal's diet. The enrichment levels, livestock grading and the trimming procedures vary somewhat between Canada and the U.S.

To summarize then we investigate consumer behavior using nutrients (the Z vector) derived from meats, eggs, fats and oils. The Z vector contains fat, cholesterol, protein and energy.

4.2 DEMAND EQUATION ESTIMATES

The most common flexible functional forms for demand systems (AIDS, Translog, Generalized Leontief) involve logarithmic or square root transformations of prices. Since the implicit prices of nutrients are often negative, these functional forms cannot be used. Of course it is possible to find other flexible functional forms that can accommodate the negativity of shadow prices. A good example is the normalized quadratic indirect utility function. Demand equations can be derived by application of Roy's theorem to this specification of the indirect utility function.

The use of these flexible functional forms in demand analysis is well established but corresponding demand equations are difficult to estimate nonlinearities in coefficient. Because of these problems, I choose to estimate a nutrient demand model based on the Stone-Geary utility function. When maximized subject to the budget constraint this utility function implies the linear expenditure system of demand equations (LES). Compared to the flexible forms, there is a serious loss in generality which is not fully compensated for by the ease of estimation.

Maximization of the Klein Rubin utility function

$$U(Z)=\Sigma a_i lg(Z_i-b_i) \qquad (4.1)$$

subject to the nutrients budget yields the linear expenditure system:

$$b_i Z_i=a_i b_i+c_i(Y_n^* -\Sigma a_i b_i)+u_i \quad (4.2)$$

with $a_i>0$, $\Sigma c_i=1$ and $Z_i-b_i>0$.
The own price elasticity of demand is calculated as $-1+(a_i/Z_i)(1-c_i)$. The cross price elasticities is $1-(c_i a_j b_j)/(b_i Z_i)$ and the income (expenditure) elasticity and $c_i Y_n^*/b_i Z_i$.

This demand system satisfies all the theoretical restrictions of zero homogeneity, adding up and a symmetric negative semidefinite matrix of substitution terms. The additive nature of the utility function and the resulting linear demand system makes the LES extremely restrictive but the restrictions are no more than those dictated by economic theory (Deaton 1972). ai is the minimum quantity of product i purchased while, ci is known as the marginal budget share for product i.

Estimates of the LES system are often interpreted as follows: the consumer buys necessary quantities ai of different goods and allocates the remaining income (Yn*-Σaibi) among the goods in fixed proportion ci. ai and ci are generally taken to be positive but this is not a necessary assumption. For example if ai is negative then levels of consumption of commodity i are very low at low levels of supernumerary income (Yn*-Σaibi). If ci is negative, then consumption of commodity i decreases as supernumerary income increases. This interpretation is particularly convenient in the nutrients case where some implicit prices are negative and where the reasons to reduce levels of certain nutrients are obvious. In this study we only pay attention to elasticities because they are most relevant from a policy perspective.

There are very few parameters to estimate but the restrictions are consistent with economic theory. The restrictive nature of LES comes solely from the functional form and the additive nature of the underlying utility function.

4.3 ECONOMETRIC METHODOLOGY

As discussed earlier the first model we estimate consists of the hedonic price equations for agricultural commodities:

$$P_i = \alpha_i + \Sigma \beta_j z_{ij} + e_i \quad (4.3)$$

We noted earlier that $\beta_j^* = \beta_j(P,Y,Z^*)$. Since (P,Y,Z^*) vary over time, we could not assume (as above) that β is constant if we were applying the model to time series data. We would have to specify a nonlinear model

$$P_i = \alpha_i + \Sigma \beta_j(P,Y) z_{ij} + e_i \quad (4.4)$$

where $\beta(P,Y) = \beta_j(P,Y,Z(P,Y))$.

However with cross-section data (aggregated over consumers), we can avoid this problem. (P,Y) is constant within the cross-section and this leads to constant β's. In this case (4.3) is the right specification of shadow prices for cross section estimation. $E(e_i e_j) \neq 0$ in general, but if all commodities (1,..n) have the same nutrient variables ($z_{ij}>0$), then OLS is an appropriate method to estimate β. Therefore P is a vector of cross-section observations on prices of commodities selected from meats, fats&oils and eggs. For every year the P vector is the price vector of beef loincuts, beef hipcuts, beef rib cuts, beef chuck cuts, beef stewing lean, ground beef, pork loin cuts, pork shoulder cuts, pork sausages, pork bacon, chicken, turkey, margarine, butter, canola oil and, salad dressing. In summary then we investigate the consumer behavior using nutrients (the Z vector) derived from meats, eggs, fats and oils. The Z vector contains fat, cholesterol, protein and energy.

The LES nutrient demand equations are:

$$b_iZ_i=a_ib_i+c_i(Y_n^* - \Sigma a_ib_i)+u_i \quad (4.5)$$

Normally one equation can be dropped since the sum of expenditures is equal to the exogenous income. This implies a linear dependency between (u1, u2...un), but here $\Sigma b_iZ_i=Y_n^*$ which is stochastic; so it is not clear that one equation must be dropped here. Because the cov(e,u)#0, cov(b,u)#0 and cov(Yn*,u)#0, the LES must be estimated by three stage least squares (3SLS) where (b,Yn*) are treated as endogenous. The first stage uses (P,Y) as instruments for (b,Yn*). P here is a vector of commodity prices and the consumer price index, and Y is a vector of disposable income per capita and total food expenditure. These instruments (b,Yn*) are correlated with (P,Y) but uncorrelated with the error term ui.

In summary 3SLS is employed because implicit prices and the nutrients budget are not truly exogenous in the nutrient demand equations. Firstly these prices are econometric estimates from the hedonic price equation (rather than data) and thus have a stochastic distribution presumably correlated with error terms in the demand equations. Secondly and as suggested earlier, since nutrients are produced jointly, the implicit prices are generally endogenous to the consumer even though the household production function may exhibit constant returns to scale. Thus SUR estimates are inconsistent. In analyzing the results and testing for the stability of the parameters we will put more emphasis on the 3SLS estimates because they are consistent given the theoretical specification of our model.

Chapter V

ECONOMETRIC RESULTS: IMPLICIT PRICE EQUATIONS

Before presenting the results, it might be useful to remind ourselves that the hedonic equation is not a price determination equation. We argued earlier that it is just one way to discover what the consumer is willing to pay for different nutrients and linear programming could have been used in lieu of Econometrics. The above factors naturally imply that in assessing the results econometric criteria will play a minor role but in the estimation of demand equations we will specifically take into account the stochastic nature of the shadow prices. After all, they are estimated and like any econometric estimates their distribution explicitly depends on the structure of the error term. This arises independently of the endogeneity of the shadow prices. From an econometric perspective, it is interesting to note that multicollinearity is inherent to the problem we studied because nutrients are in general joint outputs and the consumer's valuation of nutrient A must be expected to be conditional upon the levels of other nutrients (particularly the negatively perceived ones).

In contrast to protein we hypothesized that energy, fat and cholesterol would have negative implicit prices. The results are generally consistent with the above expectations. Tables 1 and 2 give the implicit prices and the corresponding T ratios on a yearly basis. The mean prices for different nutrients are also given in Table 1.

TABLE 1

IMPLICIT PRICES WITH HEDONIC=F(PROTEIN, FAT, ENERGY AND CHOLESTEROL)

YEAR	PROTEIN	FAT	ENERGY	CHOLESTEROL
1960	-0.00135678	-0.0189222	0.00029237	-0.00109143
1961	-0.10577590	-1.38822491	0.02290197	-0.10822741
1962	0.01069925	0.03363001	-0.00136715	0.03143809
1963	0.00688211	-0.01668372	-0.00154417	0.02317155
1964	0.00579262	-0.05550485	-0.00076732	0.02835175
1965	0.00696176	-0.03563574	-0.00110158	0.01769332
1966	0.01101169	0.01183935	-0.00179111	0.02163768
1967	0.01222174	0.02643445	-0.00229465	0.03159204
1968	0.00769538	0.00809188	-0.00181740	0.01412981
1969	0.00757684	0.00671593	-0.00126203	0.01800948
1970	0.00576765	-0.00627632	-0.00156399	0.02401944
1971	0.00385166	-0.02625035	-0.00131220	0.01045011
1972	0.00755727	0.01499451	-0.00098722	0.00406017
1973	0.00789483	0.01725580	-0.00133414	0.00802145
1974	0.00244204	-0.06074908	-0.00193278	0.02552168
1975	0.01350813	-0.02434845	-0.00245761	0.01579088
1976	0.02092062	0.06369987	-0.00303468	0.00965954
1977	0.00905376	-0.015946643	-0.00431431	0.02090122
1978	0.01192753	0.04260021	-0.00644571	0.02211889
1979	0.015381171	0.18876099	-0.00848065	0.01110343
1980	0.00796026	0.10531228	-0.00434365	-0.00506561
1981	0.00459747	0.05144619	-0.00067461	-0.00737034
1982	0.01020309	0.11510776	0.00059584	0.01190040
1983	0.00524757	0.06070489	-0.00104110	-0.00388872
1984	0.00901178	0.04835260	-0.00105458	-0.00172907
1985	0.02526488	0.22112938	-0.00366876	0.00550713
1986	0.03193787	0.25461155	-0.00530696	-0.00530696
1987	0.02676836	0.15127361	-0.00119066	-0.01309574
MEAN	0.00646445	-0.008092	-0.0013321	0.00747510

TABLE 2

THE T TEST AND RSQUARE FOR THE IMPLICIT PRICES

INTERCEPT	TINTERCEPT	TPROTEIN	TFAT	TENERGY	TCHOLESTEROL	RSQUARE;
26.25	4.18	-1.64	-2.31	1.49	-1.03	0.47
25.830	7.87	1.52	0.52	-0.82	2.74	0.52
28.78	8.63	0.96	-0.26	-0.91	1.99	0.43
29.48	9.60	0.88	-0.91	-0.49	2.64	0.54
29.66	9.17	1.01	-0.55	-0.67	1.57	0.37
28.84	8.01	1.43	0.16	-0.98	1.72	0.41
30.01	7.24	1.38	0.32	-1.09	2.18	0.47
33.35	8.02	0.87	0.10	-0.86	0.97	0.23
32.54	10.55	1.15	0.11	-0.80	1.67	0.35
33.59	10.87	0.87	-0.10	-0.99	2.23	0.46
36.99	10.24	0.50	-0.37	-0.71	0.83	0.20
35.25	12.11	0.22	0.26	-0.67	0.40	0.21
36.10	14.25	1.46	0.34	-1.03	0.91	0.32
43.63	10.77	0.28	-0.75	-0.94	1.80	0.42
52.88	9.87	1.18	-0.23	-0.90	0.84	0.31
56.06	9.05	1.58	0.52	-0.96	0.45	0.31
59.14	7.48	0.54	-0.10	-1.07	0.76	0.22
60.06	7.01	0.65	0.25	-1.48	0.74	0.28
63.78	7.68	0.87	1.14	-2.01	0.38	0.38
78.64	14.42	0.68	0.97	-1.56	-0.27	0.28
90.00	22.14	0.53	0.64	-0.33	-0.52	0.11
90.81	26.66	1.40	1.70	0.34	1.00	0.31
101.97	27.26	0.66	0.82	-0.55	-0.30	0.13
106.00	19.74	0.78	0.45	-0.39	-0.09	0.095
105.33	23.25	2.61	2.45	-1.59	0.35	0.57
108.50	17.70	2.44	2.09	-0.57	-0.25	0.50
116.21	12.79	1.38	0.84	-0.26	-0.41	0.24

Implicit prices for protein were positive in all but the first two years. This suggests that consumers value protein positively as expected. The average implicit price is 0.00646 units.

Implicit prices for energy are also negative in all but the first two years. Negative implicit prices should be expected in developed societies given the popularity of low energy food products. The reason for the negative valuation is the (correct) belief that consumed but unburnt energy is fattening. For underdeveloped countries one would expect a positive valuation for this nutrient.

In contrast the estimated shadow prices for fat are somewhat surprising. Implicit prices are both positive (18 years) and negative (10 years). It is a paradox that consumers should value fat positively when the health awareness movement was in full force. This result is consistent with observed behavior. In fact, this paradox has been noted as early as 1985:

> "For example, a reason often cited for the decline in red meat consumption and the simultaneous increase in chicken consumption is that the public is concerned about the amount of fat, cholesterol and calories in the diet. The irony is the recent tremendous popularity of breaded deep fried chicken products in the fast food industry. Another irony is that in a recent national survey of 4,556 people across Canada it was found that the most popular method of cooking meat in the home was frying. If health concerns are driving the shift from beef to chicken, why this paradoxical consumer behavior" (Stewart and Robbins 1985).

In retrospect this ambiguity is not surprising: as a nutrient fat has harmful effects and from this angle consumers value it negatively. On the other hand fat is also an input that enhances taste, odor and palatability in the cooking process. As such, it is positively valued. It is probably this dual role played by fat that rationalizes the results obtained and which are obviously compatible with the observed behavior. The relation between fat and health and tastes makes the valuation of this nutrient ambiguous, but the ambiguity is inherent to the consumer behavior.

Alternatively the ambiguous for fat results could reflect the fact that we treated fat as a homogeneous product. A distinction should be made between animal-based fat and vegetable-based fat, between saturated fat and mono/polyunsaturated fat. This distinction could prove important in the light of the fact that much of the increase in the fat availability is coming from the vegetable source (margarine, shortening and shortening oil). For example in 1963, 75% of the fat intake by Canadians came from animal sources and 25% was vegetable origin. This is a sharp contrast to 1983 where fat from animal sources represented 59% while that from vegetable sources jumped from 25% to 41%.

The implicit prices for cholesterol are positive until 1979 (with the exception of 1961-62) and are generally negative in the 80's. These results are consistent with a structural shift in consumer demand for red meats and eggs due to increased concern about cholesterol content. This shift is thought to have taken place in the late 70's early 80's. The implicit prices of cholesterol from 1960 to 1988 suggest that this is indeed so.

An important feature of the results is that the intercept is always positive. This suggests that other nutrients or other nonnutrient characteristics also influence consumer demand for agricultural products.

5.1 ECONOMETRIC RESULTS (SUR) DEMAND SYSTEM

In the first set of results, SUR was applied to the LES without deleting any equation. Here the nutrient expenditures biZi sum to Yn* which is stochastic. Thus it is not necessary to omit one equation from the estimation, in contrast to standard application of the LES. The estimates are significantly different from zero, but the Durbin Watson statistics

are rather low indicating the presence of autocorrelation. Table 3 gives the SUR estimates. Even after correcting for first order autocorrelation the Durbin-Watsons are still low, which suggests higher order autocorrelation.

Table 3 presents the estimates from the four equations W1 (protein), W2 (fat), W3 (energy) and W4 (cholesterol) with and without correction for autocorrelation. The results are generally different qualitatively and quantitatively, and the T ratios are invariably high. The low Durbin-Watson statistics suggest that the model may well be misspecified.

The interpretation of the structural parameters in LES models is generally based on goods and positive goods prices. In our case some implicit prices are negative and the traditional interpretation must be adapted accordingly. Here we will interpret elasticities and simply note that in the case of SUR all T ratios are highly significant.

Even when we impose the restriction that Sci=1 the above results still hold (see Table 4 below). We also estimated the system by deleting one equation and checked whether the results were invariant with respect to deleted equations. As is obvious from Tables 5-7, the results are qualitatively and quantitatively different in general. This is not surprising given the substantial autocorrelation in the model (Berndt and Savin 1975) and the endogeneity of Ynut (Yn*, i.e. the sum of the nutrient expenditures Sbi*Zi).

TABLE 3

LINEAR EXPENDITURE SYSTEM 1960-1987: SUR (NO EQUATION DELETED)

THE MODEL ESTIMATED

	DURBIN-WATSON
W1=A1*IP1+B1*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)	1.2466
W2=A2*IP1+B2*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)	0.617
W3=A3*IP1+B3*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)	0.416
W4=A4*IP1+B4*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)	0.413

PARAMETERS	ESTIMATES	T RATIO
A1	41.51620	25.84000
A2	-0.8878	10.010
A3	-14.271	-47.60
A4	14.6800	52.030
B1	-0.1370	-9.060
B2	0.9410	26.40
B3	-0.1575	-7.40
B4	-0.23630	6.20

MODEL ESTIMATED ESTIMATES WITH CORRECTION FOR AUTOCORRELATION

	DURBIN-WATSON
W1=A1*IP1+B1*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)	0.943
W2=A2*IP1+B2*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)	1.910
W3=A3*IP1+B3*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)	0.637
W4=A4*IP1+B4*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)	0.480

PARAMETERS	ESTIMATES	T RATIO
A1	41.01966	20.28
A2	-17.87900	-2.99
A3	1117.150	-20.51
A4	339.4500	47.31
B1	-0.01252	-6.37
B2	0.85919	19.44
B3	-0.65139	-5.88
B4	0.20486	6.02

TABLE 4

LINEAR EXPENDITURE SYSTEM WITH B1+B2+B3+B4=1: SUR (NO EQUATION DELETED)

THE MODEL ESTIMATED

W1=A1*IP1+B1*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)
W2=A2*IP1+B2*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)
W3=A3*IP1+B3*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)
W4=A4*IP1+B4*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)

PARAMETERS	ESTIMATE	T RATIO	EQUATIONS	DURBIN-WATSON
A1	37.79	30.81	W1	0.669
A2	-6.059	-3.43	W2	0.400
A3	-60.082	-11.03	W3	0.381
A4	279.770	88.96	W4	0.662
B2	1.14737	34.31		
B1	-0.0127	-9.59		
B3	-0.13752	-5.56		

TABLE 5

LINEAR EXPENDITURE SYSTEM WITH B1+B2+B31+B4=1: SUR
(EQUATION W2 DELETED)

THE MODEL ESTIMATED

W1=A1*IP1+B1*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)
W3=A3*IP1+B3*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)
W4=A4*IP1+B4*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)

PARAMETERS	ESTIMATE	T RATIO	EQUATIONS	RSQUARE	DURBIN-WATSON
A1	29.09717	16.56	W1	0.97	0.523
A2	66.96561	20.67	W3	0.79	0.564
A3	-145.79	-4.69	W4	0.91	0.670
A4	-147.57	-3.40			
B1	-0.005783	-1.52			
B3	-0.08369	-1.26			
B4	0.95604	11.30			

TABLE 6

LINEAR EXPENDITURE SYSTEM WITH B1+B2+B3+b4=1 : SUR (EQUATION W4 DELETED)

THE MODEL ESTIMATED

B4=1-B2-B1-B3
W1=A1*IP1+B1*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)
W3=A3*IP1+B3*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)
W2=A2*IP1+B2*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)

PARAMETERS	ESTIMATE	T RATIO	EQUATIONS	RSQUARE	DURBIN-WATSON
A1	33.307	15.93	W2	0.99	1.36
A2	246.69	5.61	W3	0.82	0.673
A3	-208.07	-4.64	W1	0.98	0.675
A4	-0.44921	-0.00			
B2	- 0.42747	-3.48			
B3	0.00354	2.42			
B4	-0.00496	-0.21			

TABLE 7

LINEAR EXPENDITURE SYSTEM WITH B1+B2+B3+B4=1: SUR (EQUATION W3 DELETED)

MODEL ESTIMATED

W1=A1*IP1+B1*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)
W3=A3*IP1+B3*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)
W2=A2*IP1+B2*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)

PARAMETERS	ESTIMATE	T RATIO	EQUATIONS	RSQUARE	DURBIN-WATSON
A1	40.75	26.61	W1	0.97	0.740
A2	-26.102	-4.84	W2	0.99	0.823
A3	1282.16	24.30	W4	0.61	0.789
A4	295.59	56.89			
B1	-0.00986	-6.84			
B2	0.76020	21.57			
B4	-0.02830	- 0.98			

TABLE 8

LINEAR EXPENDITURE SYSTEM: 3SLS WITH ENDOGENOUS IMPLICIT PRICES

MODEL ESTIMATED

W1=A1*IP1+B1*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)
W2=A2*IP1+B2*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)
W3=A3*IP1+B3*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)
W4=A4*IP1+B4*(YNUT-A1*IP1-A2*IP2-A3*IP3-A4*IP4)

PARAMETERS	ESTIMATE	T RATIO	EQUATIONS	DURBIN-WATSON
A1	-17.78	-1.23	W1	0.120
A2	-40.62	-6.59	W2	0.665
A3	-134.19	-4.21	W3	0.726
A4	299.45	21.88	W4	1.967
B1	0.02987	2.14		
B2	0.83501	15.89		
B3	-0.06493	-1.89		
B4	-0.20170	-2.47		

5.2 ECONOMETRIC RESULTS (3SLS) DEMAND SYSTEM

In using SUR, we recognized explicitly that the error terms across equations are related and maintained that the implicit prices and the budget were exogenous. But as pointed out earlier, the implicit prices are generally endogenous and the use of SUR does not correct for the resulting simultaneous equation bias. Therefore 3SLS was used. The 3SLS estimates are generally different from the SUR estimates. The previous Table 8 gives gives the 3SLS estimates.

The 3SLS results are qualitatively and quantitatively different from the SUR results. For example, A1 is negative and insignificant. Nevertheless the D.W statistics are very low in both models.

TABLE 9

ELASTICITIES USING SUR RESULTS AND 3SLS RESULTS

3SLS ELASTICITIES

	PROTEIN	FAT	ENERGY	CHOLESTEROL	INCOME
PROTEIN	-44.65	-0.103	-0.016	-0.0051	0.5995
FAT		-1.450	-0.765	1.0960	0.8244
ENERGY			42.510	0.0590	0.127
CHOLESTEROL				-22.23	-0.125

SUR ELASTICITIES

	PROTEIN	FAT	ENERGY	CHOLESTEROL	INCOME
PROTEIN	105.5	-0.001	0.0015	-0.0055	-0.275
FAT		-1.004	0.1310	-0.0422	-0.9290
ENERGY			4.0280	0.0071	0.3080
CHOLESTEROL				-1.966	0.1466

5.3 DEMAND ELASTICITIES

For the sake of comparison, we present the elasticities using the SUR and 3SLS estimates. Notice the sharp contrast between these estimates. Since the implicit prices in the demand model are stochastic, the 3SLS estimates are presumably superior. In terms of elasticities (table 9) and using the 3SLS results we note that for protein, fat and energy the own implicit prices are negative i.e if the implicit price goes up consumption will fall. It is for energy that the own price elasticity is positive. The cross price elasticities are negative and low suggesting that little substitution takes place. That the lower part of table 9 is empty should not be interpreted to mean that elasticities are symmetric because $((\delta Xi/\delta Pj)/(Xi/Pj))$ is different from $((\delta Xj/\delta Pi)/(Xj/Pi))$. The elasticities of the fat-cholesterol and the energy-cholesterol pairs are positive suggesting that they are substitutes. From the consumer's perspective they are substitutes in the sense that all are negatively valued and the consumer's objective is not to reduce one while increasing the intake of the other but to reduce his consumption of both simultaneously. The income (nutrients expenditure) elasticities for protein, fat and energy are positive and less than one so that an increase in the nutrients budget results in a proportionately smaller increase in the demand for nutrients. This income elasticity is negative for cholesterol and indicates that an increase in the budget actually leads to a decrease in the cholesterol intake which is what one should expect if cholesterol is strongly negatively perceived by the consumer.

TABLE 10

TEST FOR THE STABILITY OF THE PARAMETERS: 1960-1973, 1974-1987

THE ESTIMATED MODEL: THE MODEL BELOW COMBINED WITH ITS UNRESTRICTED VERSION

```
PARMS A11 A12 A21 A22 A31 A32 A41 A42 B11 B12 B21 B22 B31 B32 B41 B42;
A11=A12; A21=A22; A31=A32; A41=A42; B11=B12; B21=B22; B31=B32; B41=B42;
ABW1=(A11*BIP1+B11*(BYNUT-A11*BIP1-A21*BIP2-A31*BIP3-A41*BIP4))
   +(A12*AIP1+B12*(AYNUT-A12*AIP1-A22*AIP2-A32*AIP3-A42*AIP4));
ABW2=(A21*BIP1+B21*(BYNUT-A11*BIP1-A21*BIP2-A31*BIP3-A41*BIP4))
   +(A22*AIP1+B22*(AYNUT-A12*AIP1-A22*AIP2-A32*AIP3-A42*AIP4));
ABW3=(A31*BIP1+B31*(BYNUT-A11*BIP1-A21*BIP2-A31*BIP3-A41*BIP4))
   +(A32*AIP1+B32*(AYNUT-A12*AIP1-A22*AIP2-A32*AIP3-A42*AIP4));
ABW4=(A41*BIP1+B41*(BYNUT-A11*BIP1-A21*BIP2-A31*BIP3-A41*BIP4))
   +(A42*AIP1+B42*(AYNUT-A12*AIP1-A22*AIP2-A32*AIP3-A42*AIP4));
```

UNCONSTRAINED LINEAR EXPENDITURE SYSTEM WITH 3SLS.

PARAMETER	ESTIMATE	T RATIO	EQUATION	DURBIN-WATSON
A11	-30.826	-1.41	PROTEIN	0.233
A12	-67.500	-3.68	FAT	0.372
A21	-128.23	-3.85	ENERGY	0.585
A22	-85.6800	-2.06	CHOLEST	1.107
A31	-167.74	-2.70		
A32	-101.26	1.84		
A41	258.34	6.88		
A42	433.60	13.81		
B11	0.03581	2.22		
B12	0.04458	3.21		
B21	0.55847	6.90		
B22	0.60908	4.21		
B31	-0.03457	-0.80		
B32	-0.04241	-1.36		
B41	-0.11887	-2.50		
B42	-0.07766	-3.01		

OBJECTIVE*N=69.21

CONSTRAINED LINEAR EXPENDITURE SYSTEM WITH 3SLS.

PARAMETERS	A12	A22	A32	A42	B12	B22	B32	B42
ESTIMATE	-17.78	-40.62	-134.19	299.45	0.0299	0.835	-0.0649	-0.2017
T RATIO	-1.23	-6.59	-4.21	21.88	2.14	15.89	-1.89	-2.47

EQUATION	PROTEIN	FAT	ENERGY	CHOLESTEROL
DURBIN-WATSON	0.120	0.665	0.726	1.967

OBJECTIVE*N=130.73

5.4 TESTING FOR STABILITY OVER TIME

Earlier we speculated that consumers have been primarily concerned with the nutrient content of food only during the 70's and 80's. This would imply the model developed may be valid only for that period. Table 10 reports estimates of the nutrient demand equations allowing for variation in coefficients between the period 1960-1973 and 1974-1987. The B coefficients are somewhat similar between the two periods and generally significant, indicating that the impacts of supernumerary income on nutrient demands do not differ substantially between the two periods. The hypothesis of stability of coefficients over the two periods was tested following Gallant and Joergenson (1979). In Table 10 the unconstrained model assumes that parameters are different over the two periods and the constrained version restricts coefficients to be to be identical over the two periods. The test is based on the difference in value of the least squares criteria for these two models. Under the hypothesis of stability, the statistic OBJECTIVE*N for the restricted and unrestricted models is distributed Chi-square with eight degrees of freedom (the number of restrictions on coefficients implied by stability). Thus the hypothesis of stability of coefficients between 1960-1973 and 1974-1987 is rejected at all levels of significance.

Chapter VI

SUMMARY AND CONCLUSION

There were three objectives of thi thesis: (1) to determine the shadow prices for selected nutrients; (2) to use these implicit prices to estimate the demand for nutrients and (3) to test for the stability of the demand parameters over time.

Hedonic prices equations for beef loincuts, beef hipcuts, beef ribcuts, beef chuck cuts, beef stewing lean, ground beef, pork loin cuts, pork shoulder cuts, pork sausages, pork bacon, chicken, turkey, margarine, butter, canola oil and salad dressing were estimated using annual cross section data on commodity prices and nutrient content in order to obtain implicit prices for nutrients in each year. Then a linear expenditure system was specified for nutrient demands as a function of implicit prices and supernumerary income. Since the implicit prices are stochastic, this system of equations was estimated by three stage least squares as well as seemingly unrelated regression.

The econometric results of this study suggest that (1) consumers have been valuing protein positively for the entire period 1960-1987 while energy is consistently negatively valued; (2) fat has an ambiguous valuation due the dual role of fat as a nutrient and a taste enhancer, (3) cholesterol is positively valued up to the late 70's while it is negatively valued for the 80's. This last result is consistent with the hypothesis of a shift away from food products with high cholesterol content such as eggs. Negative implicit prices are interpreted as a positive willingness to pay by the consumers for the removal of the attribute from the food product. Alternatively they can be seen as the optimal discount for people to buy the product with the undesired characteristics.

The cross price elasticities suggest that little substitution takes place among nutrients. Income elasticities indicate that protein, fat and energy are normal goods while cholesterol appears to be an inferior good. Own price elasticities for protein, fat and cholesterol have the expected sign and are very high. Demands for these three nutrients are very sensitive to own prices. Energy has a positive own price elasticity.

These results are qualitatively comparable to Eastwood et al's estimates for protein and fat. In their case the fat-protein cross price elasticity is -0.013, the protein own price elasticity is -0.009 while its income elasticity is equal to 0.075. For fat these elasticities are respectively -0.034 and 0.065. Naturally, care must be exercised in making these comparisons because of differencies in methodologies.

The hypothesis of stability of nutrient demand across the two periods was rejected. This result is not surprising. To the extent that consumers have acquired more knowledge and information about nutrition over time we would expect shifts in preferences for nutrients.

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