Modelling Structural Change in the U.S. Demand for Meat

by

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(ABSTRACT)

Recent empirical research on meat demand has debated whether or not the effects of changing meat prices can explain all the observed changes in meat consumption patterns. This thesis provides a framework for modelling and testing for structural change using three commonly used demand system — a linear demand system, an inverse demand system, and the Almost Ideal Demand System (AIDS). Emphasis is placed on the statistical adequacy of the models. Two specific issues are carefully addressed: consumer concern for cholesterol and its effect on meat demand, and the dynamics of adjustment in meat consumption.

When modelling the demand for beef, pork, chicken and turkey, none of the three demand systems are found to be statistically adequate, and consequently, cannot be used to address structural change issues for these particular data and commodities. The AIDS models are re-estimated in an attempt to model the demand for beef, pork, chicken and fish instead of turkey. The dynamic versions of the AIDS models using either a gradual shift spline path, a Farley-Hinich path, a variable measuring cholesterol awareness, or the log of the cholesterol awareness variable

are all statistically adequate. Likelihood ratio tests on these models indicate that structural change has occurred. The significance of the cholesterol variable in the demand models indicates that health concern is an important factor in meat purchasing decisions.

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Introduction

1.1 The Problem Statement

Meat, a rich source of protein and energy, is crucial to our diets. An adequate market supply of meat will benefit consumers. The meat industry will be able to accurately adjust the quantity and quality of meats supplied only if it has good information about consumers' preferences for meats. Once factors which affect the consumption of meats are identified they can be closely monitored by the industry.

Purcell (1989) presented evidence that changes in prices of competing meats such as pork and poultry cannot explain the dramatic drop in inflation-adjusted beef prices since 1979 (Figure 1.1).[1] Inflation-adjusted retail pork prices dropped only slightly between 1980 and 1986. Inflation adjusted broiler prices were stable from 1983 through 1986 and up in 1988, and during this time, per capita consumption of poultry has continued to increase (Figure 1.2). He concluded that "given what was happening to pork and poultry prices, it is difficult to accept that there has been no structural change in beef demand or that any shifts in beef demand can be explained by changes in prices of other products" (p.18).

[1]The nominal retail prices were deflated using consumer price index. All of the (quarterly) data illustrated here have also been deseasonalized. These and other relevant data are discussed in more detail in chapter three.

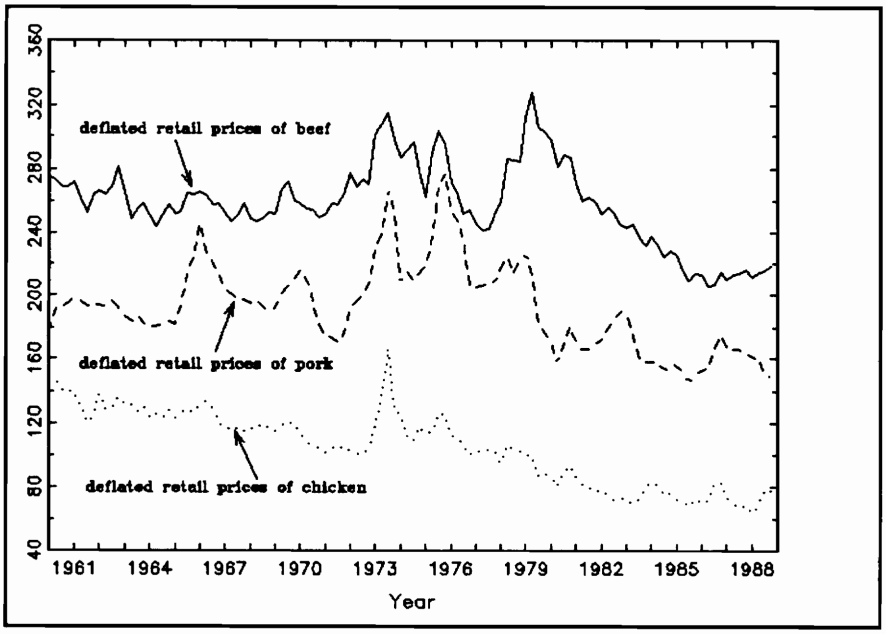

Figure 1.1 Deflated Retail Prices of Beef, Pork, and Chicken

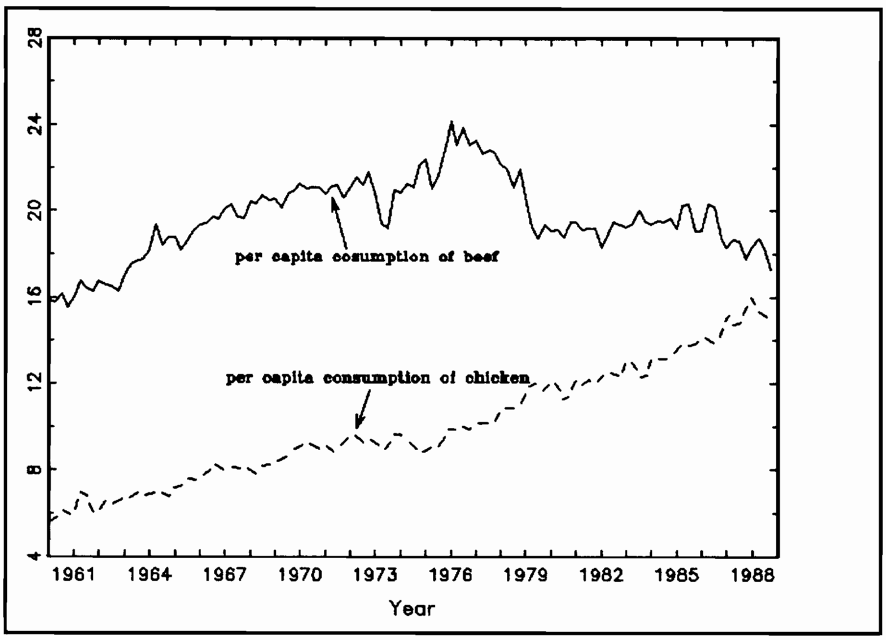

Figure 1.2 Per Capita Consumption of Beef and Chicken

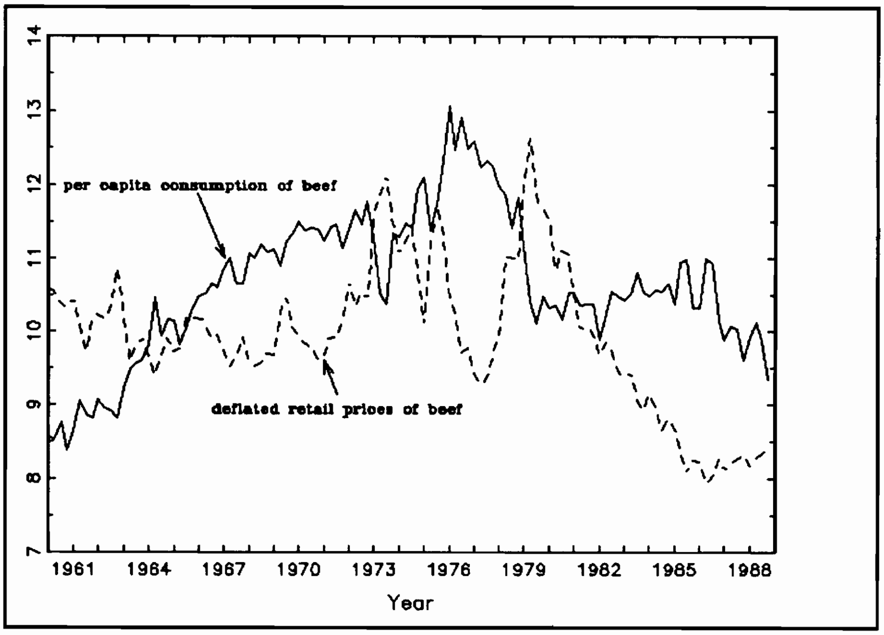

Figure 1.3 Per capita Consumption and Retail Prices of Beef

Figure 1.3, which shows the deflated retail prices and per capita beef consumption, illustrates what has been happening to beef demand since 1960. From 1960 through 1973, the inflation-adjusted price of beef was relatively stable while quantities consumed increased gradually. During the period from 1973 to 1979, an increase (decrease) in quantity demand corresponded to a decrease (increase) in price, a typical phenomenon of market adjustment. After 1979, however, the quantity demanded continued to decrease as prices also decreased dramatically. Whether these changes make sense or indicate structural change depends on what is happening to real income and other prices. In any case, the data indicate that the demand for beef has been on the decline since 1975.

Not all recent research on meat demand concurs with the conclusions of Purcell regarding these changes in demand; there is a continuing debate whether or not the effects of changing meat prices can explain all the observed changes in meat consumption patterns. There is substantial empirical evidence of substitutions from beef to poultry. However, the sources or causes of these observed changes are a matter of question. Some attribute the shifts to changes in relative prices. Others say the changes are caused by new information on the health and nutritional aspects of meat. Capps and Schmitz (1991) report that a recent national food marketing survey found that 93% of respondents were concerned about the nutritional content of foods. Almost two-thirds of those surveyed reported they had adjusted household diets in the previous three years for health or nutrition reasons. Concerns are on the rise for particular meat components, notably fat and cholesterol. If the decline in red meat consumption resulted from changing consumer tastes and preferences caused by new information regarding health and nutrition then some "structural change" for the demand for meat has occurred.

The issue whether structural change has occurred is of critical importance to the meat industry. As Moschini and Meilke (1989) note: "the observed meat consumption patterns of the last two decades cannot be fully explained by the dynamics of prices and income...this movement toward an increased importance of white meats further supports the idea that dietary concerns are partly responsible for the perceived changes in meat consumption patterns. The implications of this are particularly relevant for the beef industry, calling possibly for a quality adjustment in production and increased efforts in promotion and marketing." (p.260).

Alwang, McGuirk, and Driscoll (1991) point out that if changing relative prices and incomes account for most of the observed changes in meat demands, the red meat industry will have to improve efficiency and reduce its prices to consumers in order to maintain market shares. If shifts in tastes and preferences have produced structural change, the industry must invest in research and marketing efforts to address the concerns causing the structural change. For example, if an increase in the value of people's time is responsible for this change, investments to increase ease of product preparation might be needed. If concerns about health cause this shift, then improving the health content of the product, or changing people's perceptions about the health content, will be important. Therefore, identifying the factors that explain the observed patterns in meat consumption will provide the industry direction in adjusting themselves to the new market situation.

Empirical results differ widely from study to study with regard to the occurrence and timing of structural change in meat demands in the United States. Haidacher et al.(1982), Jolly (1983), Leuthold and Nwagbo (1977), and Moschini and Meilke (1984) found no evidence of structural change. Braschler (1983), and Wohlgenant (1982, 1986) found structural change for beef and pork. Chavas (1982), Choi and Sosin (1990), Cornell and Sorenson (1986), Moschini and Meilke (1989), and Nyankori and Miller (1982) found structural change in the demand for beef and chicken/poultry. Dahlgran (1986) and Frand (1984) argued that structural change occurred in the consumption of beef, chicken, and pork. The studies finding structural change found that the change occurred somewhere between 1969 to 1979 for the different meats.[2]

There are number of possible reasons for these diverse results. Smallwood, et al.(1986) note that these reasons include problems in the data used, the means of modeling the structural change, and the functional form. Certainly, findings of structural change are intimately tied to the statistical techniques used. Structural change in demand is a direct consequence of changes in the underlying utility function; utility is, however, a construct that is not directly observable. Analyses of structural change focus on whether the parameters of the demand functions corresponding to the underlying utility function vary or not. However, demand parameters may vary not only because of structural change but also due to model misspecification or other statistical problems.

It is important to distinguish between varying parameters due to model misspecification and "structural change". Alston and Chalfant (1991) pointed out the problem of not being able to distinguish between structural change and functional form. One way to circumvent the problem of not being able to tell why the parameters are varying is to try to model the source of structural change.[3] By modeling structural

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[2]See Appendix table A.1.

[3]Capps and Schmitz (1991) also suggested that it is necessary to formally investigate the source of structural change, and that the ideal approach is to identify and use variables that may explain shifts in the utility function. However, their reasons for suggesting this approach are different than those

change, one can hope to find a "statistically adequate model" or a model whose statistical assumptions (including parameter constancy as well as normality, no-autocorrelation, homoskedasticity, etc.— See chapter two) are all met. This approach to investigating the existence of structural change enables one to avoid the problem that without statistical adequacy, tests of structural change are of questionable validity. That is, the validity of structural change tests, and any other tests involving the parameters of an econometric model, rely heavily on the assumptions of normality, no-autocorrelation, homoskedasticity, correct functional form, and parameter constancy. If any (combination) of these assumptions are not met, the tests are most often invalid.[4]

Previous studies have not paid much (if any) attention to whether or not the statistical assumptions underlying their models and tests of structural change have been met. Given the variety of models estimated and approaches of testing or modeling structural change, it is no surprised that the results are so different. Before the conclusions of any of these studies can be taken seriously, it must be demonstrated, at a minimum, that the statistical assumptions underlying their models are valid (for more details, see section 2.3.1).

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indicated here.

[4]Perhaps the one exception to this statement is when only normality is violated. In this case, tests are asymptotically justifiable. For a more detailed discussion of these issues, see chapter two.

1.2 Objectives

The main objective of this thesis is to model and test for structural change in United States meat demand. Two issues will be carefully addressed: consumer concern for cholesterol and its effect on meat demand, and the dynamics of adjustment in meat consumption. Careful attention will also be given to the statistical properties of the demand models estimated. Recall that without first testing whether all the statistical assumptions of the model are met, subsequent hypothesis tests are rendered meaningless. In an attempt to reconcile some of the previous often conflicting results, the data and theoretical models (demand systems) most commonly found in the literature are used. In doing so, several important issues in demand (empirical) analysis are ignored. These include the issues of aggregation, errors in variables, separability, and simultaneity.

1.3 Procedures

The procedures used to reach the study's objectives are:

1). Estimate different demand systems using data most commonly used in many demand studies (see chapter 3);

a). Test models for statistical adequacy, ie., look to see if the estimated demand systems meet all the underlying statistical assumptions;

b). Respecify the demand systems if they are not statistically adequate. The respecification will depend on which statistical assumptions are invalid. If necessary, a variable measuring consumer concern of cholesterol is used to model structural change;

2). Test for "structural change" by attempting to delete those variables explaining structural change;

3). Finally, the theoretical restrictions implied by utility maximization are tested.

The organization of the thesis is as follows. Chapter two describes the general theory of demand. Three approaches used to develop empirical models are discussed. Following this, issues regarding structural change and tests for statistical adequacy are presented. The three demand systems to be investigated are described at the end of Chapter two. Chapter three describes estimation and results. The conclusions, implications, and directions for further research are then discussed in Chapter four.

CHAPTER 2

Demand Theory and Models

Section 2.1 Introduction

The purpose of this chapter is to present and discuss three different approaches to deriving empirical demand systems. Convenient and widely used functional forms (demand systems) are presented corresponding to each of these approaches. The systems are used to investigate the issue of structural change in meat demand. The main subjects will be discussed in the following order:

1.) The theory of consumer demand in general is discussed. The restrictions implied by this theory are derived. Three different approaches for deriving demand models are outlined.

2.) The issue of structural change is discussed in relation to this theory. Following this, means of testing for structural change are developed.

3.) The specific demand models used in the study are derived. For each demand system, the particular forms of the theoretical restrictions are outlined. Finally, the relevant results from three published papers selected as typical examples of how these three demand systems have been used in the literature are discussed.

Section 2.2 The Theory of demand

Section 2.2.1 The Primal Approach

Standard neoclassical demand equations are derived implicitly or explicitly from the maximization of a consumer's utility function subject to a budget constraint (see, eg. Deaton and Muellbauer, Phlips, etc.). This problem takes the form:

$$\text{Max } U(\underline{q})$$

$$\text{st. } \underline{p}'\underline{q} \leq M \qquad (2.1)$$

where U is a twice continuously differentiable, strictly quasi-concave utility function. In a system containing n commodities, $\underline{q}$ is an n×1 vector of the quantities of goods consumed (a typical element is q_i, the quantity consumed of good i), $\underline{p}$ is a vector of the prices of goods (a typical element is p_i, the price of good i), and M is total income (or expenditure). An assumption of strict monotonicity or (less strict) local non-satiation of preferences guarantees that the budget constraint holds with equality ($\Sigma_i p_i q_i = M$).[1]

The maximization problem in (2.1) can be solved by setting up the Lagrange:

$$L = U(\underline{q}) + \lambda \left(M - \Sigma p_i q_i \right). \qquad (2.2)$$

Under the assumption of interior solution, the first order conditions

[1]Monotonicity or local non-satiation says that one can always do a little bit better, ie., more is better (Varian).

for a maximum are:

$$U_i(\underline{q}) = \lambda p_i \qquad i=1,\ldots n \tag{2.3}$$

$$\Sigma p_i q_i = M, \tag{2.4}$$

where U_i is the partial derivative of U with respect to q_i, and λ represents the marginal utility of income. Equations (2.3) indicate that marginal utility of q_i must equal the market price of that commodity times the marginal utility of money, and equation (2.4) implies that all income is spent. A system of direct demand functions (or Marshallian demand functions) can be obtained by assuming that the conditions of the implicit function theorem are met so that the system of equations in (2.3) and (2.4) can be solved for $\underline{q}$:

$$\underline{q} = f(\underline{p},M) \tag{2.5}$$

This is the primal approach of deriving the demand system.

Three types of restrictions result directly from this problem. These restrictions are known as *Homogeneity of degree zero*, *Adding-up*, and the *Slutsky symmetry condition.*

The restriction of zero homogeneity of the Marshallian demands in prices and income can be derived directly from the budget constraint. If prices and total expenditure increase proportionally, the budget constraint remains unaffected and, hence, the quantity demand is unchanged. This means that only relative prices matter and consumers exhibit no money illusion.

The adding-up restriction is derived from the budget constraint and the assumption of non-satiation. Because of non-satiation, any increase in total expenditure must be entirely allocated among the different commodities. Differentiating the budget constraint with respect to M yields

$$\Sigma_i p_i \, \partial q_i/\partial M = \Sigma_i \partial(p_i q_i)/\partial M = 1 \qquad (2.6)$$

where $\partial(p_i q_i)/\partial M$ is the marginal propensity to consume good *i*, measuring how the expenditure on commodity *i* will increase in response to a one unit increase in total expenditure. The adding-up condition, as illustrated in equation (2.6), means that the marginal propensities to consume for all goods must sum to one.

Homogeneity and adding-up imply that the demand elasticities satisfy three restrictions:

(1) $\Sigma_j \, \varepsilon_{ij} = -\eta_i$ (2.7)

(2) $\Sigma_i \, w_i \varepsilon_{ij} = -w_j$ (Cournot aggregation) (2.8)

(3) $\Sigma_i \, w_i \eta_i = 1$ (2.9)

where $w_i = p_i q_i/M$. The uncompensated (Marshallian) price elasticity, ε_{ij}, and the total expenditure elasticity, η_i, are defined as follows:

$$\varepsilon_{ij} = [\partial f(\underline{p},M)/\partial p_j] \, [p_j/q_i] \qquad (2.10)$$

$$\eta_i = [\partial f(\underline{p},M)/\partial M] \, [M/q_i]. \qquad (2.11)$$

Property (2.7) follows from the homogeneity of the demand functions while properties (2.8) and (2.9) result from the adding-up property (see Deaton and Muellbauer or Phlips for a derivation of these conditions).

The mathematical expression for the Slutsky symmetry restriction takes the form:

$$(\partial q_i/\partial p_j)^c = (\partial q_j/\partial p_i)^c \qquad (2.12)$$

where $(\partial q_i/\partial p_j)^c$ indicates how quantity i will change in response to a one unit change in price j along a compensated (Hicksian) demand curve.

Equation (2.12) states that along an indifference curve, the marginal change in quantity consumed of commodity i following a price change of commodity j equals the marginal change in quantity consumed of commodity j with respect to the price change of commodity i. This symmetry condition is derived from the maximization of the utility function (problem 2.1) and the property (Young's theorem) that $\partial^2 U/\partial q_i \partial q_j = \partial^2 U/\partial q_j \partial q_i$,ie. the order of differentiation does not matter.[2] For a formal derivation of the symmetry condition, see appendix B. It can be shown that the compensated (Hicksian) demand is always downward sloping by concavity of expenditure function; this implies that $(\partial q_i/\partial p_i)^c < 0$, and the compensated own-price elasticity is negative ($\varepsilon_{ii}{}^c < 0$) (Varian). Because no income effect exists in compensated demand, from equation (2.7) it can be shown that:

$$\Sigma_j \varepsilon_{ij}{}^c = 0. \tag{2.13}$$

A similar concept will be discussed for the inverse demand functions in next sub-section.

Often, when applied studies impose symmetry on a system of Marshallian demands, they employ the Slutsky equation to do so. The Slutsky equation decomposes the price (or uncompensated) effect, $\partial q_i/\partial p_j$, into income and substitution (or compensated) effects. It can be written as (see appendix B, or Deaton and Muellbauer):

$$\partial q_i/\partial p_j = (\partial q_i/\partial p_j)^c - q_j\, \partial q_i/\partial M \tag{2.14}$$

where $(\partial q_i/\partial p_j)^c$ is the substitution effect and $q_j\, \partial q_i/\partial M$ is the income

[2]This symmetry condition can also be easily derived from the expenditure function.

effect. The substitution effect (or compensated or Hicksian cross partial) measures the change in q_i given a small change in the price of good j, holding the consumers utility level constant. The income effect accounts for the fact that as prices of goods change, the remaining income to be allocated to all goods also changes. Multiplying both sides of equation (2.14) by p_j/q_i, the Slutsky equation can be expressed in elasticity form:

$$\partial q_i/\partial p_j \; p_j/q_i = (\partial q_i/\partial p_j)^c \; p_j/q_i - q_j \; (\partial q_i/\partial M \; M/q_i) \; q_i/M \; p_j/q_i$$

$$\varepsilon_{ij} = \varepsilon_{ij}^c - w_j \; \eta_i \qquad (2.15)$$

These Slutsky equations (2.14 and 2.15) will be employed in the following discussion.

The particular form of homogeneity, adding-up, and symmetry restrictions depends on the functional form of the utility function and/or the demand system. Given a particular functional form, these three restrictions can be used to derive relationships between the unknown parameters of the function. These restrictions might take the form of relationships between elasticities (equation 2.7-2.9) or between direct parameter estimates. They are very useful in empirical analysis as they permit testing of the theoretical implications of the utility maximization assumption. In addition, following testing, estimation efficiency will be enhanced by the imposition of the restrictions. Before these assumptions can be tested or imposed, however, the unrestricted demand equations must satisfy all the statistical assumptions underlying their estimation. (This discussion is continued later in chapter two.)

Studies using the primal approach either start with a specific utility function and derive the functional form for the demand equations, or assume a functional form for the system of demand equations (not necessarily worrying about what the utility function looks like) and then impose the theoretical restrictions on this system. The former approach is not widely used because it is difficult or impossible to solve the first order conditions for most reasonable forms of utility functions. The latter approach is more widely used and is employed in this study.

Two other means of deriving or specifying demand systems are presented below: the inverse demand approach and the dual approach. Since these approaches also are derived from an assumption of utility maximization, the theoretical restrictions derived above also hold.[3] The form of these restrictions will vary with the particular demand system considered. Other details about these two approaches related to this study are discussed in the following two sections.

Section 2.2.2 Inverse Demand Systems

In some cases, people argue that quantity does not adjust to price but price adjusts to quantity. This alternative assumption is often justified in cases of agricultural products where biological lags in

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[3]The dual approach, though not specifically generated from utility maximization, is "dual" to it, so that it implies the same thing (Deaton and Muellbauer).

production tend to fix quantities available in the market at any one period. For example, in the demand for beef, the lag in production makes it difficult to adjust quantity in a short period, and prices become the major (endogenous) mechanism to clear the market. Thus, "inverse" demand equations are often used in empirical analysis of demand for agricultural products. The following exposition of inverse demand system is largely drawn from Huang (1988).

The inverse demand system of equations expresses prices as functions of quantities and total expenditure, $p_i = g^i(\underset{\sim}{q},M)$. They are derived from utility maximization as follows. The lagrangian function (equation 2.2) takes the form:

$$\text{Maximize } L = U(\underset{\sim}{q}) + \lambda(M-\Sigma p_i q_i)$$

and the optimization conditions are as shown in equations (2.3) and (2.4) before. Multiplying each equation (2.3) by q_i, summing over *i*, and solving for λ yields:

$$\lambda = \Sigma_{i=1}^{n} q_i U_i(\underset{\sim}{q})/M \qquad (2.16)$$

Substituting (2.16) into (2.3) and solving for p_i yields the inverse demand function:

$$p_i = (U_i/\Sigma_j q_j U_j)\ M \qquad (2.17)$$

These demand functions can also be written in terms of normalized prices, $r_i = p_i/M$, by

$$r_i = U_i(\underset{\sim}{q})/\Sigma_{j=1} q_j U_j(\underset{\sim}{q}) = g^i(\underset{\sim}{q}) \qquad (2.18)$$

In the context of (2.18), the budget constraint becomes $\Sigma_i r_i q_i = 1$.

Estimation of (direct or quantity dependent) demand equations (2.5) yields price elasticities ($\partial q_j/\partial p_i\ p_i/q_j$, equation 2.10). For inverse demands, the analog to these elasticities are flexibilities. The price flexibilities (or quantity elasticities; $\partial p_i/\partial q_j \; q_j/p_i$) indicate how much the price of a commodity will change given a marginal change in the available quantity of good j.

The analog to the Hicksian price effect in the direct demand system is the Antonelli substitution effect. The Antonelli substitution effect describes how much normalized prices change in response to marginal changes in the consumption of good j, keeping the consumer on the same indifference curve. This substitution effect expressed in elasticity form is:

$$\delta_{ij}^{c} = [\partial g^{ic}/\partial q_j] \; [q_j/g^{ic}] \; ,$$

where g^{ic} is the compensated price of commodity *i* and δ_{ij}^{c} is the compensated cross-price flexibility.

By Euler's theorem and the homogeneity of degree zero for demand functions, the following result holds:[4]

$$\begin{aligned} g^{ic} \; (tq_1, \; tq_2, \ldots, \; tq_n) &= t^0 \; g^{ic} \; (q_1, \; q_2, \ldots, \; q_n) \\ &= g^{ic} \; (q_1, \; q_2, \ldots, \; q_n) \qquad (2.19) \end{aligned}$$

Differentiating both sides of (2.19) with respect to t yields:

$$[\partial g^{ic}/\partial tq_1] \; [\partial tq_1/\partial t] + \ldots + [\partial g^{ic}/\partial tq_n] \; [\partial tq_n/\partial t] = 0$$

$$[\partial g^{ic}/\partial tq_1] \; q_1 + \ldots + [\partial g^{ic}/\partial tq_n] \; q_n = 0$$

$$[\partial g^{ic}/\partial tq_1] \; q_1/g^{ic} + \ldots + [\partial g^{ic}/\partial tq_n] \; q_n/g^{ic} = 0$$

$$\delta_{i1}^{c} + \ldots + \delta_{in}^{c} = 0$$

[4]Demand equations (2.17) and (2.18) are necessarily homogeneous of degree zero (in quantities and expenditure). Just as in the direct demand case, this result can be derived directly from the budget constraint.

$$\Sigma_j \delta_{ij}^c = 0$$

This is analogous to equation (2.13) in primal problem. In addition, just as the own-price substitution effects have to be negative in the direct demand approach, the Antonelli own-quantity effects are always negative, ie. $\delta_{ii}^c < 0$.

The Antonelli substitution effects can be expressed in terms of an uncompensated quantity effect and a scale effect in a manner similar to the Slutsky equation (equation 2.14 or 2.15). In elasticity form, this relationship can be written as:

$$\delta_{ij} = \delta_{ij}^c + w_j \mu_i$$

where δ_{ij} is the uncompensated quantity effect, and μ_i is the scale flexibility. The scale flexibility (also known as scale elasticity) corresponds directly to the total expenditure elasticity ($\partial q/\partial M \; M/q$ in equation 2.11), and tells how much the price of a commodity will change in response to a proportionate increase in the quantity of all commodities.

The scale flexibility can be understood more clearly through graphical illustration. Suppose $\underline{q}_a$ is the original consumption bundle producing a utility level U_a and leading to a normalized price vector $\underline{r}_a$, $\underline{r}_a'\underline{q}_a=1$. Let L_a be the line tangent to U_a at $\underline{q}_a$. The slope of L_a is $-(r_{a1}/r_{a2})$. A marginal increase in M along with a change in relative price moves the equilibrium bundle to $\underline{q}_b$ and yields more utility. L_b whose slope is $-(r_{b1}/r_{b2})$ is the line tangent to U_b and the resulting normalized price vector $\underline{r}_b$ satisfies $\underline{r}_b'\underline{q}_b=1$. Connecting a ray from the origin to $\underline{q}_b$, the ray intersects U_a at $\underline{q}_c$, which is a quantity vector scaled down proportionally from $\underline{q}_b$. Again, the normalized price vector is represented by L_c and $\underline{r}_c'\underline{q}_c$=1 is satisfied.

Figure 2.1 Decomposition of price effects for quantity changes

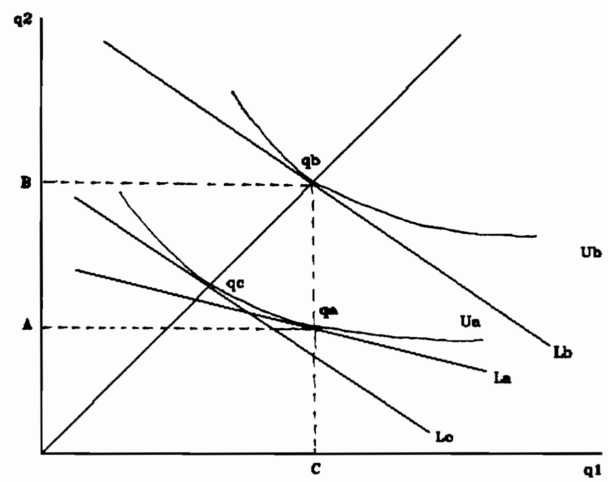

Figure 2.1 Decomposition of price effects for quantity changes

From the graph it is obvious that the total change in the price vector from $\underline{r}_a$ to $\underline{r}_b$ in response to a marginal increase in quantity can be decomposed into two parts: (1) the Antonelli substitution effect, which is reflected by the price movement from $\underline{r}_a$ to $\underline{r}_c$ in response to a proportional change of quantity vectors from $\underline{q}_a$ to $\underline{q}_c$; (2) the scale effect, which is shown by the price change from $\underline{r}_c$ to $\underline{r}_b$ in response to a proportional change of quantity vectors from $\underline{q}_c$ to $\underline{q}_b$, gives consumer a higher scale of quantity demanded and satisfaction. The total effect of this quantity change is the sum of these two effects, which can be represented by the difference in prices $\underline{r}_a$ and $\underline{r}_b$.

Let $\underline{q}^*$ be the reference consumption bundle in an arbitrary time period and $\underline{q}=k\underline{q}^*$ where k is a scalar or factor of proportion (in figure 2.1 $\underline{q}_b=k\underline{q}_c$). The inverse demands can be written as:

$$r_i = g^i(k\underline{q}^*) \qquad (2.20)$$

and the scale flexibility of the commodity *i* is expressed as:

$$\mu_i = \partial g^i/\partial k \ (k/g^i) \qquad (2.21)$$

To derive the three principal restrictions analogous to (2.4)-(2.6), we can write $g^i(k\underline{q}^*) = g^i(\underline{q}) = \Sigma_j(\partial g^i/\partial q_j)\ q_j$

(by Euler's theorem and homogeneity of degree zero)

Thus, equation (2.21) implies the following:

$$\begin{aligned}\mu_i &= \partial g^i/\partial k \ (k/g^i)\\ &= \partial[\Sigma_j(\partial g^i/\partial q_j)q_j]/\partial k \ (k/g^i)\\ &= \Sigma_j(\partial g^i/\partial q_j)(\partial q_j/\partial k) \ (k/g^i) \qquad [\text{assuming } \partial^2 g^i/\partial q^i \partial k=0]\\ &= \Sigma_j \partial g^i/\partial q_j \ q^*_j \ (k/g^i)\\ &= \Sigma_j \partial g^i/\partial q_j \ (q_j/g^i)\\ &= \Sigma_j \delta_{ij}\end{aligned}$$

where δ_{ij} is the cross-price flexibility of commodity *i*. Since

$$\Sigma_i r_i q_i = 1 = \Sigma_i g^i(\underline{q}) \ q_i \ . \qquad (2.22)$$

Equation (2.22) can be differentiated with respect to q_j to yield:

$$\begin{aligned}0 &= \Sigma_i \partial g^i/\partial q_j \ q_i + g^j\\ &= \Sigma_i \partial g^i/\partial q_j \ (q_j/g^i) \ g^i q_i + g^j \ q_j\\ &= \Sigma_i \partial g^i/\partial q_j \ (q_j/g^i) \ g^i q_i/M + g^j \ q_j/M\\ &= \Sigma_i \delta_{ij} w_i + w_j\end{aligned}$$

$$\Sigma_i \delta_{ij} w_i = -w_j \quad \text{(Cournot aggregation)}. \qquad (2.23)$$

Summing (2.23),

$$\Sigma_i w_i \ \Sigma_j \delta_{ij} = -\Sigma_j w_j \quad \text{and} \quad \Sigma_j w_j = 1$$

$$\Sigma_i w_i \mu_i = -1 \quad \text{(scale aggregation).} \qquad (2.24)$$

In order to impose these theoretical restrictions, it is useful to estimate the inverse demand function written as a function of the scale variable k and the time period reference vector $\underline{q}^*$. To see this note that by totally differentiating (2.20), we will have:

$$dr_i = \Sigma^n_{j=1}(\partial r_i/\partial q_j^*)\ dq_j^* + (\partial r_i/\partial k)\ dk \qquad i=1,2,\ldots,n$$

$$dr_i/r = \Sigma^n_{j=1}(\partial r_i/\partial q_j^*)\ q_j^*/r\ dq_j^*/q_j^* + (\partial r_i/\partial k)\ k/r\ dk/k. \qquad (2.25)$$

Further, recall that the compensated price flexibility, or the price change of the ith commodity with respect to a quantity change of the jth commodity holding utility constant, takes the form:

$$\begin{aligned}\delta_{ij}^c &= (\partial g^{ic}/\partial q_j)\ (q_j/g^{ic})\\ &= (\partial r_i/\partial q_j)\ (q_j/r_i)\\ &= (\partial r_i/\partial q_j^*)\ (\partial q_j^*/\partial q_j)\ (q_j^* k/r_i)\\ &= (\partial r_i/\partial q_j^*)\ (q_j^*/r_i) \qquad (2.26)\end{aligned}$$

$$\text{since } \partial q_j^*/\partial q_j = 1/k$$

and the scale flexibility, which shows the effect of the ith commodity price on the proportional change in all quantities demand, is written as:

$$\mu_i = (\partial g^i/\partial k)\ (k/g^i) = (\partial r_i/\partial k)\ (k/r_i) \qquad (2.27)$$

Thus, equation (2.25) can be rewritten as:

$$dr_i/r = \Sigma^n_{j=1}\delta_{ij}^c(dq_j^*/q_j^*) + \mu_i(dk/k) \qquad (2.28)$$

which is a useful equation to estimate since the parameters can be easily interpreted, and homogeneity, Cournot aggregation and scale aggregation can be imposed without difficulty. To estimate this function, however, we need to calculate k and $\underline{q}^*$ in order to define the variables dq_j^*/q_j^* and dk/k.

To see how the scale variable k and the reference vector $\underline{q}^*$ can be measured, recall that

$$\underline{q}_t = \underline{q}_{0t}^* \, D(U_0, \underline{q}_t) \qquad (2.29)$$

where $\underline{q}_t$ is the quantity vector of consumption at time t, $\underline{q}_{0t}^*$ is the reference quantity vector associated with $\underline{q}_t$ (yields U_0, the base utility level), and $D(U_0, \underline{q}_t) = k_{(1\times1)}$ is the distance function on the utility U_0 in the base period for the quantity vector q_t. Suppose that $\underline{p}_0'\underline{q}_0$ is the minimum cost of reaching U_0 in the base period. Consequently, it follows that $\underline{p}_0'\underline{q}_0 \le \underline{p}_0'\underline{q}_{0t}^*$. Using (2.29), to rewrite this equation yields:

$$(\underline{p}_0'\underline{q}_0)\ [\underline{q}_{0t}^* \, D(U_0, \underline{q}_t)] \le (\underline{p}_0'\underline{q}_{0t}^*)\ (\underline{q}_t)$$

$$(\underline{p}_0'\underline{q}_0)\ D(U_0, \underline{q}_t) \le \underline{p}_0'\underline{q}_t \qquad \text{or}$$

$$D(U_0, \underline{q}_t) \le (\underline{p}_0'\underline{q}_t)/(\underline{p}_0'\underline{q}_0) \ .$$

Consequently, the distance function (or k) can be approximated by $(\underline{p}_0'\underline{q}_t)/(\underline{p}_0'\underline{q}_0)$ which is simply the base weighted Laspeyres quantity index. The closer the base period quantity vector and the equilibrium demand in the base period, the more accurate the approximation. Using this index to measure the scale variable, and deflating the actual quantity vector, then $\underline{q}_{0t}^*$ will be obtained.

The system of inverse demand equations described in (2.28) can now be estimated. The particular specification for inverse demand system used in this study will be discussed in more detail in section 2.4.2, and the results presented in chapter 3.

Section 2.2.3 The Dual Approach

The third and final approach to modelling consumer demand considered here is the dual approach. More and more researchers employ dual approaches in their empirical work. The main reason for this is that the dual approach considerably simplifies and clarifies derivations and results that are otherwise quite difficult. There are two methods that are referred to as dual approaches. The first approach uses an indirect utility function, which expresses the maximum possible utility as a function of prices and income ($V(\underline{p},M)$). The other dual approach results from the assumption that a consumer minimizes total expenditures subject to a specific level of utility.[5] Here we focus on the latter only.

The mathematical formulation of the expenditure minimization problem is (Varian): $\text{Min } \Sigma_j p_j . q_j$

$$\text{st. } U(\underline{q}) \geq U^0$$

The result of this minimization problem is the expenditure function $E(\underline{p},u)$ which expresses the minimum expenditure required to reach utility level U^0 given prices $\underline{p}$. The properties of the expenditure function

[5]"Quasi-profit" functions have also been used to study consumer demand. By applying Hotelling's lemma, the derived demand function can be obtain from a quasi-profit function.

are:[6]

1. $E(\underline{p},U)>0$ for $\underline{p}>0$ and $U>0$ (non-negativity);
2. if $\underline{p}' \geq \underline{p}$, then $E(\underline{p}',U) \geq E(\underline{p},U)$ (non-decreasing in $\underline{p}$);
3. concave and continuous in $\underline{p}$;
4. $E(t\underline{p},U) = tE(\underline{p},U)$, $t>0$ (positively linearly homogeneous in prices); and
5. if $U \geq U'$, then $E(\underline{p},U) \geq E(\underline{p},U')$ (non-decreasing in U).

By Shepard's lemma, the Hicksian demand functions (or compensated demand functions) can be obtained directly by differentiating the expenditure function with respect to prices:

$$q^c{}_i(\underline{p},U) = \partial E(\underline{p},U)/\partial p_i = f^c(\underline{p},U) \qquad (2.30)$$

Since the expenditure function is homogeneous of degree one, the derivatives of the expenditure functions, or the compensated demand functions, are homogeneous of degree zero. Note that for a given level of utility $E(\underline{p},u)=M$, and that $E(\underline{p},u)$ may be inverted to solve for u as a function of $\underline{p}$ and M (ie. $u=\xi(\underline{p},M)$). This can then be substituted into the compensated demand function (equation 2.30) to yield a Marshallian demand function.

When a functional form is specified for $E(\underline{p},u)$, the compensated cross partials (Hicksian cross-price effects) can be derived directly from equation (2.30). It can be shown that the Slutsky equation and all other conditions from primal approach still hold in the dual case. An advantage of using dual approach is that direct restrictions on

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[6]See Varian for a derivation of these properties.

parameters of the demand system can be derived in many cases. For example, when using the primal approach, symmetry restrictions are often derived by using the Slutsky equation (2.15). These restrictions can often only be imposed at a point. In contrast, the symmetry restriction can be imposed directly in the dual approach by equating the corresponding coefficients across equations and, thus these restrictions can be made to hold globally.

Thus far, we have discussed three approaches for modelling the consumer demands. The relevant primal approaches discussed included the conventional utility maximization problem where quantity demand is derived as a function of prices and expenditure and a variant of this approach which yielded inverse demand equations. Inverse demand equations describe price as a function of quantities and expenditure as it is assumed that prices adjust to clear the market instead of quantities. The third approach considered was the dual problem which assumes that expenditures are minimized subject to a certain level of utility. Before we explicitly specify the particular models chosen in this study as examples of each of these three approaches, the issues of structural change are addressed.

Section 2.3 Structural Change and Statistical Adequacy

Structural change is described and defined in this section. Various methods of modelling and testing structural change are discussed. How statistical adequacy relates to the issue of structural change is also discussed. Following this, the statistical assumptions of the empirical models are outlined and tests to detect departures from these assumptions are presented.

Section 2.3.1 The Issue of Structural Change

Structural change may be interpreted as a change in preferences, which is reflected by a change in the parameters of the underlying primal (or dual) function. Graphically, structural change could result in a change in the slope of demand function and/or a parallel shift in some direction.

Suppose the utility function is $U(\underline{q};\alpha) = u$, where U is conditioned on the vector of parameters α of the utility function. Structural change from period t_o to t_1 implies that $U(\underline{q};\alpha_{t0}) \neq U(\underline{q};\alpha_{t1})$, which, in effect, means that $\alpha_{t0} \neq \alpha_{t1}$. Many different forces can drive this "structural change". For example, if parameter α is a function of factor z; ie., $\alpha = D(z)$, then $z_{t0} \neq z_{t1}$ implies $\alpha_{t0} \neq \alpha_{t1}$, and structural change may be observed. Thus, "structural change" can occur even though the function D(.) itself is not changing. It is important to note that the exact parameters of primal utility function are not observed. Only the parameters of demand function are observed. Structural change can only be observed when the changes in preferences or the mechanisms determining preferences imply change in the demand equations.

In some cases, z_t cannot be observed but can be accounted for in different ways. For example, if z is trending over time, then expressing α as a function of t might capture the essence of the change. Other times, if there is a near discrete change in α (eg. $\alpha=\alpha_1$ for $t<t_1$ and $\alpha=\alpha_2$ for $t\geq t_1$), then the change can be modelled by a binary (0-1) or dummy variables. More elaborate functions of time can also be used to model changes in parameters. For example, Moschini & Meilke consider a gradual structural change scenario, where the parameters are constant until time t_1 and then increases linearly until time t_2, after which they remain constant at their new values. Specifically, they model changes in the parameters by assuming they depend on a variable h_t defined as follows:

(i) $h_t = 0$ for $t=1,\ldots,t_1$;

(ii) $h_t = (t-t_1)/(t-t_2)$ for $t=t_1+1,\ldots,t_2-1$;

(iii) $h_t = 1$ for $t=t_2,\ldots,T$.

They refer to this gradual switching path as a spline path.[7]

In situations where z_t, the factor causing the parameters to change, is observable—the ideal situation, a direct measure of it should be used to model the structural change. For example, consumers'

[7]Note that both the inclusion of a time trend and/or dummy variables to model parameter changes can also be considered a "simple" spline function.

concern for healthy food and, in particular, concern over cholesterol, may be a key factor causing the change in meat demand. Consequently, a logical way to model structural change in meat demand may be to find or construct some measure of consumers concern for cholesterol which can be used in defining a spline function.[8]

In modelling structural change as described here, one can assume that either all or some subset of the parameters change in the same or different ways (eg. different functions of z_t or even functions of different z_t's). For example, Moschini & Meilke assume that all parameters of their demand functions change gradually and thus, in addition to the usual independent variables, they included interactions of all these variables with h_t.

Testing for structural change within this set up is straightforward. The assumption of no structural amounts to testing whether the coefficients of the terms that incorporate z_t (or h_t) are significantly different from zero or not. If the coefficients are not significantly different from zero, then no structural change is found. For example, in the case where all the parameters are assumed to change at a specific point in time and thus z_t is a dummy variable, a test of structural change amounts to an F-test of the significance of all the slope and intercept dummy variables. This test is similar to the commonly used F-test comparing two regimes employed in many studies with

[8]Brown and Schrader (1990) incorporated a measure of information about cholesterol in a model of the U.S. demand for shell eggs. Although their index, based on medical journal articles, is different from that used in this study, the idea is very similar.

various functional forms (eg. Chavas, 1983; Alston and Chalfant, 1991).

In previous studies of demand for meats, the major focus has been on the problem of estimating the theoretical model under the assumption that all the statistical assumptions are met. Authors then typically proceed by testing for parameter stability using either an F-test after arbitrarily determining a break point (Leuthold and Nwagbo; Braschler), or fitting a spline function similar to those discussed above and testing the significance of the switching regime (Moschini and Meilke, 1984, 1989; Nyankori and Miller; Dahlgran). One reason the results of these studies may have differed so widely is that they rarely test the statistical adequacy of their models. Consequently, it is unknown whether the rejection of the hypothesis of no structural change can be attributed to real structural change or due to some statistical misspecification of the model.[9]

A way to deal with this problem is to separate the statistical model from the theoretical one (Spanos). Within the Spanos framework, the statistical model is interpreted as summary of the sample information without any theoretical meaning and a model which satisfies all the underlying statistical assumptions on which it is based. A logical test for structural change then becomes: modeling the types of factors hypothesized to influence "demand shifts" directly such that a statistically adequate model can be obtained (e.g. its parameters are stable and all other assumptions are met), and then testing to see

[9]The nature of the data used and how they are aggregated may also be affecting the result. These issues are ignored in this study.

whether these factors can be excluded from the model. If they cannot, then one cannot reject structural change. The validity of structural change tests and any other tests involving the parameters of an econometric model rely on assumptions of normality, no-autocorrelation, homoskedasticity, and parameter constancy. If any (combination) of these assumptions are not met, the tests are most often invalid, and the hypothesis of structural change cannot be tested (see below for a more detailed discussion). Once a statistically adequate model is found, then the theoretical model can be tested by imposing theoretical restrictions.[10]

Section 2.3.2 Statistical Assumptions and Tests

In this section, the statistical assumptions underlying the estimation of a system of equations (multivariate linear regression model) such as a system of demand equations are presented. The tests for these assumptions are then described.

To describe the statistical assumptions for the multivariate linear regression model, it is convenient to use the following notation. Define $\underline{y}_t$ (m×1, with m commodities being considered) to be the vector of dependent variables and $\underline{X}_t$ (k×1) to be the vector of independent

[10]Note that for a given sample, there could be more than one statistically valid model. In this case, the competing statistically adequate models can be compared using conventional model selection criteria such as R^2, Robustness, etc.

variables. The statistical model is specified as: $\underline{y}_t = \underline{B}'\underline{X}_t + \underline{u}_t$, where $\underline{B}$ is an (m×k) matrix of unknown parameters. The underlying assumptions are:

[A.1] $f(\underline{y}_t|\underline{X}_t;\theta)$ is normal which implies $f(\underline{u}_t|\underline{X}_t;\theta)$ is normal,

[A.2] $f(\underline{y}_t|\underline{X}_t=\underline{x}_t)=\underline{B}'\underline{x}_t$, is linear in $\underline{X}_t$,

[A.3] $Cov(\underline{y}_t|\underline{X}_t=\underline{x}_t)=E(\underline{u}_t\underline{u}_t'|\underline{X}_t=\underline{x}_t)=\Omega$ is homoskedastic,

[A.4] $\theta=(\underline{B},\Omega)$, where $\underline{B}=\Sigma_{22}^{-1}\Sigma_{21}$ and $\Omega=\Sigma_{11}-\Sigma_{12}\Sigma_{22}^{-1}\Sigma_{21}$, the statistical parameters of interest, $\Sigma_{11}=cov(\underline{y}_t)$, $\Sigma_{22}=cov(\underline{X}_t)$, and $\Sigma_{12}=cov(\underline{y},\underline{X})$, are time invariant,

[A.5] $(\underline{y}_1,\underline{y}_2,\ldots\underline{y}_T)$ is an independent sample sequentially drawn from $f(\underline{y}_t|\underline{X}_t;\theta)$, $t=1,2,\ldots T$.

Each of these assumptions is tested to assess the statistical adequacy of the model. If any of the assumptions is invalid, an alternative more general model will be specified in an effort to find a statistically adequate model (see Spanos, 1986, 1989). For example, if the no-autocorrelation assumption is violated [A.5], an alternate assumption such as asymptotic no-autocorrelation can be made in which case the relevant statistical model is a dynamic linear regression model (basically, lagged dependent and explanatory variables also appear in the statistical model). No tests on parameter restrictions are conducted until a statistically valid model is identified. Violation of any of these assumptions will have severe consequences for hypothesis testing. In general, hypothesis tests will be meaningless. For example, if we have the wrong functional form (linearity violated), OLS estimates of β, σ^2 and their corresponding standard errors will be biased. Conducting hypothesis tests which involve these parameters will be worthless. A violation of the homoskedasticity assumption, on the other hand, results in unbiased estimates of β but the estimates of their standard errors will be biased. The consequences of violating the assumption of no-autocorrelation depends on the cause of the violation. For example, if no-autocorrelation is violated due to omitted lagged variables, then estimates of all the coefficients and their standard errors will be biased. If the errors are "truly" autocorrelated, $\hat{\beta}$ is unbiased but the estimates of its standard errors are biased. If normality alone is violated, tests regarding the unknown $\hat{\beta}$'s are justified asymptotically only. If the parameters of the model change over time, all estimates will be biased. Consequently, it is crucial to ensure that these assumptions are satisfied. Statistical adequacy is considered an essential pre-requisite before any tests can be conducted.

The assumptions [A.1]-[A.5] are tested using the following misspecification tests:

[A.1] Multivariate Normality (extended Skewness-Kurtosis Test (Mardia, 1974, Spanos, 1986)):

The skewness and Kurtosis coefficients for a random vector $\underline{u}_t$ with mean 0 and covariance Ω are defined by $\alpha_{3,m} = [E(\underline{u}_t'\Omega^{-1}\underline{u}_t)^3]^{1/2}$ and $\alpha_{4,m} = E(\underline{u}_t'\Omega^{-1}\underline{u}_t]^2$, respectively. $\alpha_{3,m}$ and $\alpha_{4,m}$ represent the 3rd and 4th moments. Under the assumption of normality, $\alpha_{3,m}=0$ and $\alpha_{4,m}=3$. The hypotheses $\alpha_{3,m}=0$ and $\alpha_{4,m}=3$ are tested separately using a procedure proposed by Mardia(1974, 1970).

Asymptotically, the test statistics are:

$\tau_{1s}(p) = (T/6)\hat{\alpha}_{3,m}{}^2\{[(m+1)(T+1)(T+3)]/[T((T+1)(m+1)-6)]\} \sim \chi^2(p)$

where $p=(1/6)m(m+1)(m+2)$ and $m=$# of equations in system,

$\tau_{1k}(p) = \{T/[8m(m+2)]\}[\hat{\alpha}_{4,m}-m(m+2)]^2 \sim \chi^2(p)$

where p is defined as above. τ_{1s} and τ_{1k} represent the skewness and kurtosis test statistics, respectively.

[A.2] Linearity (test of functional form)

The linearity test statistic $\tau_2(.)$ is based on the significance of Γ in the auxiliary regression(system): $\underline{y}_t = \underline{B}_0'\underline{x}_t + \Gamma\Psi_t + \underline{v}_t$, where $\Psi_t=(\underline{\hat{Y}}_{1t}{}^2, \underline{\hat{Y}}_{1t}\underline{\hat{Y}}_{2t}, \ldots \underline{\hat{Y}}_{1t}\underline{\hat{Y}}_{mt}, \underline{\hat{Y}}_{2t}{}^2, \ldots \underline{\hat{Y}}_{mt}{}^2)$. The null hypothesis is: $\Gamma=0$, tested using a likelihood ratio test. The test statistic is distributed $\chi^2(p)$, where p is the number of restrictions imposed (see Spanos, 1986).

[A.3] Homoskedasticity

The homoskedasticity test $\tau_3(.)$ is based on the significance of Δ in the auxiliary regression (system): $\underline{w}_t = \underline{c}_0 + \Delta'\Psi_t + \underline{v}_t$, $\underline{w}_t=(\hat{U}_{1t}{}^2, \hat{U}_{1t}\hat{U}_{2t}, \ldots \hat{U}_{mt}{}^2)$, and Ψ_t is as defined above. The null hypothesis is: $\Delta=0$, tested using a likelihood ratio test. The test statistic is distributed $\chi^2(p)$, where p is the number of restrictions imposed (see Spanos, 1986).

[A.4] No-autocorrelation

The no-autocorrelation $\tau_4(.)$ is based on the significance of D in the auxiliary regression (system): $\underline{\hat{u}}_t = \underline{B}_0'\underline{x}_t + D'\underline{\hat{u}}_{t-1} + \underline{v}_t$. The null hypothesis is: $D=0$, tested using a likelihood ratio test. The test statistic is distributed $\chi^2(p)$, where p is the number of restrictions imposed (see Spanos, 1986).

[A.5] Parameter Time Invariance

Parameter time invariance of the parameters is tested informally by plotting the recursive least square estimates of the parameters ($\hat{\underline{B}}, \hat{\Omega}$) to see if they vary over time.[11]

The underlying assumption for each single test listed here is that, the system of equations being tested satisfies all of the statistical assumptions except that which is being tested. Given that this assumption is not likely to be valid, these tests can only be regarded as a general indication of whether or not the assumption being tested is met, and not interpreted as a "proper" test (Spanos, 1986). Consequently, Spanos suggests conducting all misspecification tests and interpreting them altogether to assess what is the likely interpretation of the test results. For example, Spanos notes that if the no-autocorrelation assumption is violated, the misspecification tests of parameter time invariance and linearity will usually indicate problems. Once the no-autocorrelation problem is remedied, misspecification tests of the other assumptions often indicate no more problem. Spanos concludes by recommending that if no-autocorrelation appears to be a problem, this should be remedied first.

Note that the "goodness of fit" of an equation or a system of

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[11]The recursive least-squares estimation method amounts to estimating the coefficients using at least k.m observations first, and then estimating recursively by increasing the sample size by one up to T (total number of observations).

equations has very little to do with the adequacy of an estimated regression (Spanos, 1986). That is, one cannot judge the adequacy of an estimated regression on the basis of the reported R^2, or the significance of the estimated coefficients, the cross plot or the plot of the actual and fitted values. A high R^2 is not the proper criterion for a "good" estimated statistical model.

For the three functional forms used in this study, tests for statistical adequacy (eg. normality, linearity, homoskedasticity, autocorrelation, parameters t-invariant etc.) will be conducted on a base model. That is, models that don't include structural change variables. If needed, the models will be modified to account for structural change. A variable that is expected to account for structural change in meat demand (eg. consumer concern for cholesterol) will be included along with more complete dynamic specifications (if required) in an attempt to find models that are statistically adequate.

In the next section, three demand systems which illustrate the three theoretical approaches discussed in section 2.2 are developed to study the demand for meats in the United States. For each demand system chosen, the specific functional form and theoretical restrictions are specified. The testing procedures and results are also briefly summarized.

Section 2.4 Model Specification

The three general functional forms chosen for consideration in this thesis have been previously used to study meat demand. These systems are: a linear demand system found in "Structural Change in the Demand for Meat" by Jean-Paul Chavas; an inverse demand system in "An Inverse Demand System for U.S. Composite Foods" by Kuo S. Huang; and the Almost Ideal Demand System (AIDS) in "Modeling the Pattern of Structural Change in U.S. Meat Demand" by Giancarlo Moschini and Karl D. Meilke. Below, these models are presented along with their theoretical restrictions. Then, the procedures used to test structural change (if any) and the relevant empirical results of these three papers are summarized.

Section 2.4.1 The Linear Demand System

Chavas uses the primal approach and specifies a linear functional form for the demand equations without considering the type of utility function that would produce such a system of demand equations. The demand functions are written as:

$$(\Delta q_{it}/q_{i,t-1}) = \beta_{i0} + \Sigma^{N}_{j=1} \varepsilon_{ij} (\Delta p_{jt}/p_{j,t-1}) + \eta_i (\Delta M_t/M_{t-1}) + e_{it} \tag{2.31}$$

where q_i = consumption of beef, pork, and chicken

p_j = price of beef, pork, chicken, and 'all other goods'

M = total expenditure

ε_{ij} = price elasticity of demand for the ith commodity

η_i = income elasticity of demand for the ith commodity

β_{i0}, ε_{ij}, and η_i are parameters to be estimated

e_{it} is the error term.

Function (2.31) expresses the percentage change in quantity consumed as a function of percentage changes in prices and income. The error term e_{it} is assumed to be serially uncorrelated and normally distributed with mean zero and covariance:

$$E(e_{i,t}\ e_{j,t+k}) = 0 \quad \text{for } k\neq 0$$

$$\sigma_{ij} \quad \text{for } k=0.$$

The demand functions (2.31) are estimated for three meat items (poultry, beef, and pork) by using the seemingly unrelated regression (SUR) technique. The data used in Chavas's paper are annual data on U.S. per capita consumption of poultry, beef and pork for the period 1950–1979. Symmetry and homogeneity restrictions are imposed (the absence of the adding-up restriction results because only a subset of the commodities in the budget set are investigated).

The homogeneity and symmetry restrictions expressed in elasticity form can be written as:

$$\text{Homogeneity}: \Sigma^{N}_{j=1}\varepsilon_{ij} + \eta_i = 0 \qquad (2.32)$$

$$\text{Symmetry}: w_i(\varepsilon_{ij} + w_j\eta_i) = w_j(\varepsilon_{ji} + w_i\eta_j)$$

These restrictions are derived directly from Slutsky equation (2.15) and the restriction (2.7) in the previous subsections.

Chavas used this model to examine the issue of structural change. He handled the structural change problem by allowing the β's to change after 1970 only. Initially, Chavas imposed the restrictions (2.32) and used data from the period 1950–1970 to estimate (2.31).[12] Thus, he assumed no structural change during this first period. Further, he did not test any of underlying statistical assumptions, but concluded that a reasonable demand system resulted. Then he separated the period 1971–1979 into two parts arbitrarily (1971–1974; 1975–1979), and tested if structural change occurred during either of the two parts of this second period by F-tests. The results suggested that structural change occurred for beef and poultry, but not pork, in the last part of the decade(1975–1979). The price and income elasticities of beef decreased during the last few years, while the income elasticity of poultry increased. His model and results are summarized in table 2.1 at the end of the chapter.

Chavas's linear demand system will be employed as one base to estimate the demand for meats in this thesis. The empirical estimation of these models will be presented in chapter three.

2.4.2 The Inverse Demand System

Huang approximated a large-scale inverse demand system in differential form using equations (2.28) which was derived earlier. That is, his complete inverse demand system is defined as follow:

$$\dot{r}_1 = \delta_{11}{}^c\dot{q}_1 + \delta_{12}{}^c\dot{q}_2 + \ldots\ldots + \delta_{1n}{}^c\dot{q}_n + \mu_1\dot{k} \qquad (2.33)$$

[12]1950-1970 is referred to as the first period while the period 1971-1979 is the second period.

.   .

.   .

$$\dot{r}_n = \delta_{n1}^c\dot{q}_1 + \delta_{n2}^c\dot{q}_2 + \ldots\ldots + \delta_{nn}^c\dot{q}_n + \mu_n\dot{k}$$

where $\dot{r}_i$: relative change in the normalized price $= dr_i/r$

$\dot{q}_i$: relative change in the reference quantity $= dq_j^*/q^*$

$\dot{k}$: relative change in the scale of quantity demand $= dk/k$

δ_{ij}^c: compensated price flexibility; see equation (2.27)

μ_i: scale elasticity; see equation (2.28)

The theoretical restrictions imposed (once again, not tested in Huang's study) on this system of equations are as follows:

(1) Adding-up (scale aggregation): $\Sigma^n_{i=1}w_i\mu_i = -1$

(2) Homogeneity: $\Sigma^n_{j=1}\delta_{ij}^c = 0$

(3) Symmetry: $\delta_{ji}^c/w_i = \delta_{ij}^c/w_j$

(4) Negativity: $\delta_{ii}^c < 0$

and the Slutsky equation $\delta_{ij} = \delta_{ij}^c + \mu_i w_j$. (See section 2.2.2 for a discussion of these theoretical restrictions).

Huang used a constrained maximum likelihood method to estimate the system (2.33). He estimated a system of demand equations for 13 aggregate food categories and a non-food sector for 1947 through 1983. He did not explicitly model meat alone, nor was he concerned specifically with the issue of structural change (In fact he assumed there was none). His results showed that the estimated own-price flexibilities are elastic for meats and the estimated compensated cross-price flexibilities for red meats and poultry are complementary to most of the other commodity categories. The estimated scale elasticities are negative and larger than one (in absolute value) for meats.

In this thesis, Huang's inverse system is used to model the demand of meat alone. Thus, weak separability between meats and other commodities is assumed.[13] No attempt is made to replicate Huang's results.

Section 2.4.3 The Almost Ideal Demand System

The AIDS model, originally proposed by Deaton and Muellbauer (1980), is an example of applying the dual approach discussed in section 2.2.3. It begins with the log expenditure function:

$$\log C(\underline{p},u^0) = \alpha_0 + \Sigma_j \alpha_j \log p_j + 1/2\ \Sigma_i \Sigma_j \beta_{ij}^* \log p_i \log p_j + u\beta_0\ \pi_j\ p_j^{\beta j} \qquad (2.34)$$

where C represents the expenditure function, the minimum cost of achieving utility level u^0

u is the unobserved level of utility

p are prices

α, and β are parameters to be estimated.

The quadratic form allows for the interactions between prices. This expenditure function is a flexible functional form, ie., it is general enough to act as a second order approximation to any arbitrary cost

[13]The preferences are (weakly) separable if the whole commodity vector q can be partitioned into N groups. Separable preferences are represented by a utility function of the form

$$U = U[u_1(\underline{q}_1),\ u_2(\underline{q}_2), \ldots, u_N(\underline{q}_N)]$$

for sub-vectors $\underline{q}_1, \ldots, \underline{q}_N$ and some function U which is increasing in all its arguments.

function[14] (Chambers, 1988). Applying the logarithmic version of Shepard's lemma to (2.34) yields

$$\partial \log C(\underline{p},u)/\partial \log p_i = p_i q_i(\underline{p},u)/C(\underline{p},u)$$

and the dependent variable can be expressed as a budget share:

$$w_i^c = \alpha_i + \Sigma_j \beta_{ij} \log p_i + \beta_i u \beta_0 \pi_j p_j^{\beta_j} \quad (2.35)$$

where w_i^c is the Hicksian budget share. If equation (2.34) is solved for u as a function of p and M (=C) and substituted into (2.35), the Marshallian demands in budget share form result:

$$w_i = \alpha_i + \Sigma_j \beta_{ij} \log p_i + \beta_i \log(M/P) \quad (2.36)$$

where P is the AIDS Price Index defined by

$$\log P = \alpha_0 + \Sigma_j \alpha_j \log p_j + 1/2\ \Sigma_i \Sigma_j \beta_{ij} \log p_i \log p_j \quad (2.37)$$

and $\beta_{ij} = 1/2(\beta_{ij}^* + \beta_{ji}^*) = \beta_{ji}$ (2.38)

The model defined by (2.36) to (2.38) is the AIDS model. Equation (2.36) provides a first-order approximation to the general unknown relationship between w_i, log M, and the log p's.

The relevant theoretical restrictions implied by utility maximization are:

Adding up : $\Sigma_j \alpha_j = 1$, $\Sigma_j \beta_j = 0$, $\Sigma_j \beta_{ij} = 0$ (2.39)

Homogeneity : $\Sigma_j \beta_{ij} = 0$ (2.40)

Symmetry : $\beta_{ij} = \beta_{ji}$ (2.41)

---

[14] A functional form can provide a flexible approximation to some underlying function if it is possible to choose its parameters such that the function value, gradient, and hessian terms of the underlying function are exactly reproduced at any arbitrary point. This can only be accomplished if there are at least as many parameters as there are independent function value, gradient, and hessian effects. (Driscoll).

These restrictions can be employed to "test" the theory, or improve estimation efficiency, and the homogeneity restriction may be examined equation by equation since it does not require cross-equation restrictions.

The AIDS model has four desirable characteristics: (1) it provides a first-order approximation to any arbitrary demand system derived assuming utility-maximization behavior; (2) it allows non-linear and consistent aggregation over consumers (Deaton and Muellbauer, 1980); (3) except for P which is commonly approximated by an alternative price index, it is linear in its parameters and easy to estimate; and (4) the homogeneity and symmetry restrictions can be tested easily since they require linear restrictions on fixed parameters (although symmetry requires cross-equation restriction).

The linear version of the AIDS system can be written as:

$$w_{it} = \alpha_i + \Sigma_j \beta_{ij} P_{jt} + \beta_i x_t + \Sigma_k \alpha_{ik} D_k + e_{it} , \qquad (2.42)$$

where $P_{jt} = \ln(p_{jt})$, where p_{jt} is nominal price of good j at time t

$(i,j) = 1,\ldots,n$ index the goods, $t = 1,\ldots T$ indexes time

$w_i = p_i q_i / M$, where M is total expenditures on the four meats.

$x_t = \ln(M/P)$, where P is the AIDS price index. (This is approximated by the Stone geometric index $[\ln(P) = \Sigma_i w_i P_i]$).

D_k is an intercept shifter for quarter k: k=1,2,3 (quarterly data are used).

e_{it} : error term

In addition to the theoretical restrictions shown above, for this particular model, adding-up requires $\Sigma_i \alpha_{ik} = 0$.

Moschini and Meilke used an AIDS model to examine structural change of meats demand in the United States. They used quarterly data for disappearances of meats over the period 1967-I to 1987-IV and retail prices. The quantity data for beef, pork, and chicken are the same as what we will use in this study (see below). Moschini and Meilke also use personal consumption expenditure for fish and seafood on a quarterly basis which were obtained from unpublished U.S. Department of Commerce data.

Moschini and Meilke modelled structural change by assuming all parameters followed a similar time path modelled by a variable denoted as h_t (see below). Consequently, the model is rewritten as:

$$w_{it} = \alpha_i + \gamma_i h_t + \Sigma_j(\beta_{ij} + \theta_{ij} h_t)P_{jt} + (\beta_i + \theta_i h_t)x_t + \Sigma_k(\alpha_{ik} + \gamma_{ik} h_t)D_k + e_{it} \qquad (2.43)$$

with additional parametric restrictions: $\Sigma_j \theta_{ij}=0$ for homogeneity; $\Sigma_i \gamma_i=0$, $\Sigma_i \theta_{ij}=0$, $\Sigma_i \theta_i=0$, $\Sigma_i \gamma_{ik}=0$ for adding-up; and $\theta_{ij}=\theta_{ji}$ for symmetry, where θ_{ij}, γ_i, θ_i, and γ_{ik} are parameters to be estimated. If $\gamma=0$ and $\theta_{ij}=0$, $\theta_i=0$ for all i,j , then no structural change is found.

They further simplified the estimation and allowed a parsimonious representation of dynamic behavior by using a first difference form:

$$\Delta w_{it} = \gamma_i \Delta h_t + \Sigma_j \left[\beta_{ij} \Delta p_{jt} + \theta_{ij} \Delta(h_t P_{jt})\right] + \beta_i \Delta x_t + \theta_i \Delta(h_t x_t) + \Sigma_k[\alpha_{ik} \Delta D_k + \gamma_{ik} \Delta(h_t D_t)] + u_{it} . \qquad (2.44)$$

Several different parameter paths (h_t) were specified similar to those mentioned earlier. They assumed that the residuals from equations (2.44) are multivariate normally distributed with mean zero. They also assumed that the residuals are contemporaneously correlated with each other and that the non-contemporaneous correlations are zero., ie.

$$E(u_{it}) = 0 ,$$

$$E(u_{it}\, u_{jt}) = \omega_{ij} ,$$

$$E(u_{it}\, u_{is}) = 0 \quad \text{for } t \neq s.$$

Moschini and Meilke estimated their first-difference AIDS model using the iterative seemingly unrelated regressions procedure. To estimate the gradual shift model (discussed in section 2.3.1), they estimated the parameters of the model using maximum likelihood for all possible values of t_1 and t_2 to define their spline function in a pre-specified range (t_1 from 1967(1) to 1983(4), t_2 from 1971(1) to 1987(4), and $t_1 < t_2$). They argue that this maximum likelihood estimator gives consistent, asymptotically normal and asymptotically efficient estimates.

In order to use estimated elasticities to evaluate and describe the structural change, the authors argue that "one can attribute bias to structural change if it significantly changes expenditure shares" under the hypothesis that prices and expenditure levels are held constant. The measure of bias is $B_i = w_i^a - w_i^b$, where w_i^a, w_i^b denote the *i*th good share after and before structural change, respectively. If $B_i > 0$ then the structural change is biased in favor of the *i*th good and vice versa.

In evaluating if structural change has a significant effect on demand elasticities, the Marshallian elasticities are computed as follows (after structural change):

$$\varepsilon_{ii} = (\beta_{ii} + \theta_{ii})/w_i^a - (\beta_{ii} + \theta_i) - 1$$

$$\varepsilon_{ij} = (\beta_{ij} + \theta_{ij})/w_i^a - (\beta_{ii} + \theta_i)(w_j^* /w_i^*)$$

$$\eta_i = (\beta_i + \theta_i)/w_i^a + 1$$

Substituting w_i^a by w_i^b and setting θ=0 will give the elasticities before structural change. For more detail about how these equations are derived, see appendix C.

Their results show that the values of the parameters defining the path of structural change (h_t) that maximize the set of likelihood functions are t_1^*=1975(4) and t_2^*=1976(3). The hypothesis of no structural change (testing for the significance of h_t) is rejected at the 0.05 significance level. Three similar tests for specific groups of variables are also performed. The hypothesis of no structural change in intercept parameters or in seasonal parameters is rejected while structural change in price and expenditure parameters cannot be rejected. In addition, Moschini and Meilke re-estimated (2.43) assuming h_t followed a Farley-Hinich path. The Farley-Hinich path (t/T), which is equivalent to defining h_t to be a time trend, is not rejected at the 5% probability level, again indicating structural change.

The results of Moschini and Meilke also show that structural change is significantly biased against beef, in favor of chicken and fish, and it is neutral for pork.

In addition to the previous two demand systems, the AIDS models used by Moschini and Meilke will be employed in this thesis to study the demand for meats. The empirical estimation of these models will be presented in chapter three. A summary of the results of three papers chosen for closer scrutiny in this study are presented table 2.1.

This chapter described the general theory of consumer demand. The primal, the inverse demand and the dual approaches were discussed. For each approach, the theoretical restrictions were derived. Further, the issue of structural change and the methods of testing for statistical adequacy were discussed. Finally, the three specific demand systems—the linear demand system, the inverse demand system, and the almost idea demand system which are going to be estimated in this thesis were presented along with their theoretical restrictions. The empirical results from three papers which have used these specifications to model meat demand were also summarized.

In chapter three these three demand systems are estimated in an attempt to find a statistically adequate model. Once an adequate model is found, all the theoretical restrictions imposed will be tested. In addition, the hypotheses of no structural change will also be tested.

Table 2.1 Summaries of data, approaches, and results of three "typical" demand studies

Author	Chavas (1983)	Huang (1988)	Moschini & Meilke (1989)
Data	Annual 1950-1979	Annual 1947-1983	Quarterly 1967(1)-1987(4)
Meats	beef,pork,fish	13 food categories	beef,pork,fish, chicken
Method	Linear demand system w/ random coefficient	Inverse demand system	AIDS model w/ spline coefficient
Findings with respect to structural change	Structural change in beef & poultry in post-1975 period	N/A	Structural change in beef, chicken, and fish in post-1975 period

CHAPTER 3

Data and Empirical estimation

Section 3.1 Introduction

The purpose of this chapter is to present and discuss the empirical results obtained applying three different demand systems to the study of meat demand in the United States. These systems, a linear approximation of a demand system, an inverse demand system, and the AIDS system were presented in chapter 2. Here, the data used to estimate the systems are discussed. Then the models are estimated with no symmetry or homogeneity imposed using ordinary least squares (OLS) on an equation by equation basis. This is equivalent to seemingly unrelated regression (SUR) for the system since the independent variables are the same for each equation and no cross-equation restrictions are imposed. The discussed statistical assumptions in section 2.3.2 are tested for these models. Once a statistically adequate model is obtained, the tests for structural change and theoretical restrictions are conducted.

The data used are quarterly retail prices and disappearance for beef, pork, chicken and turkey. For beef and pork, quantities are disappearance in retail weight equivalent as published by the U.S.Department of Agricultural (USDA) in Livestock and Meat Situation (LMS), and in Livestock and Poultry Situation (LPS). The quantities of chicken and turkey are the total of young and mature chicken and turkey disappearance as published by USDA in Poultry and Egg Situation (PES) and in LPS. Disappearance (lbs.) is deflated to a per capita basis using the population estimates obtained in the Survey of Current Business, published by the U.S. Department of Commerce. The price series used are the retail beef and pork prices published in LMS and LPS, and the retail prices of chicken and turkey published in PES and LPS. The summary statistics for these data are presented in table 3.1.

Figures 3.1–3.3 and 1.3 illustrate the seasonally adjusted real retail prices (deflated by consumer price index) and per capita quantities demanded for the four meats over the period 1960–1988. The beef data illustrated in figure 1.3 showed prices were relatively stable up to 1973 while quantities consumed were gradually increasing. From 1979 onwards, the quantity demanded decreased despite prices that decreased dramatically. Figures 3.1–3.3 show that chicken and turkey demands have trended steadily upward, while their real prices have been falling. In contrast, per capita pork consumption has fluctuated considerably around a constant mean. Similarly, the price of pork has also generally fluctuated around a constant mean.

Figure 3.4 presents real consumer expenditures on the four meats. Total expenditure on these four meats increased up until 1973, was relatively unstable and then decreased dramatically after 1979. Figure 3.5 shows the allocation of expenditure shares among the four meats. The market share of beef has continuously decreased since 1976, the shares of pork and turkey have been relatively stable, though turkey shares have grown in the 1980's. Chicken shares have grown substantially since late 1970's.

Table 3.1 Summary statistics of variables

Variables	Mean	Standard Deviation	Min	Max
quantity of beef (lb)	19.6888	1.8771	15.50	24.30
quantity of pork (lb)	15.0035	1.3609	11.30	17.90
quantity of chicken (lb)	10.0310	2.7187	5.10	15.80
quantity of turkey (lb)	2.3664	1.3094	0.60	5.90
price of beef (cents/lb)	153.1009	67.6256	76.00	259.40
price of pork (cents/lb)	112.7888	46.6532	51.60	195.50
price of chicken (cents/lb)	57.4095	16.6594	36.30	95.80
price of turkey (cents/lb)	55.9666	16.7570	25.97	97.57
expenditure on 4 meats (cents/lb)	5471.9190	2414.8170	2349.25	9350.69
cholesterol (million subscriptions)	63.3570	86.2409	0.0	406.16

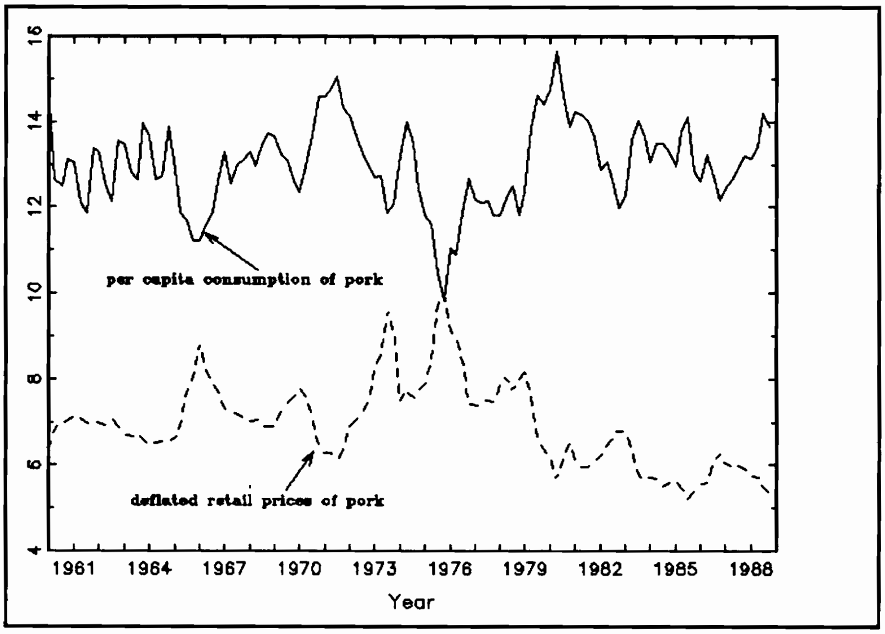

Figure 3.1 Per Capita Consumption and Retail Prices of Pork

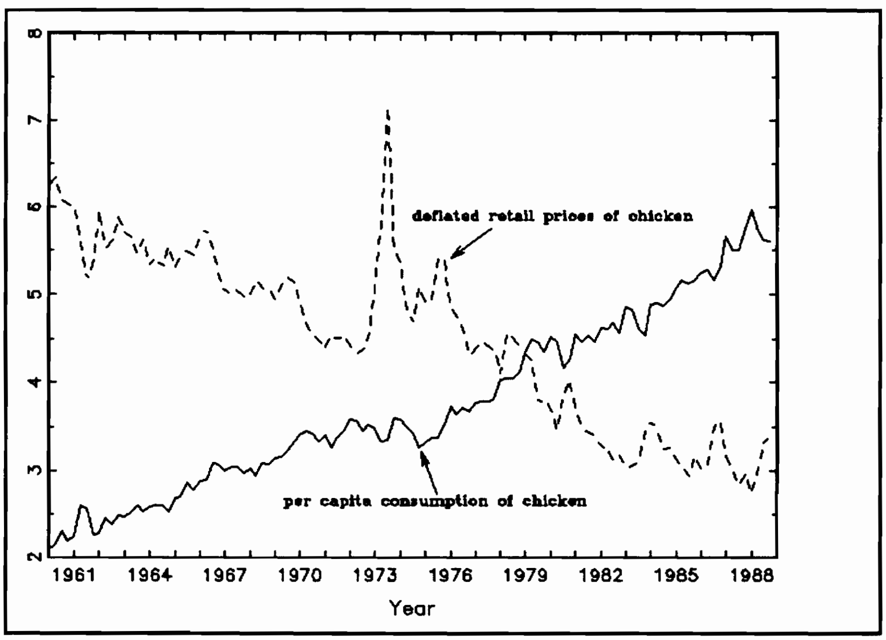

Figure 3.2 Per Capita Consumption and Retail Prices of Chicken

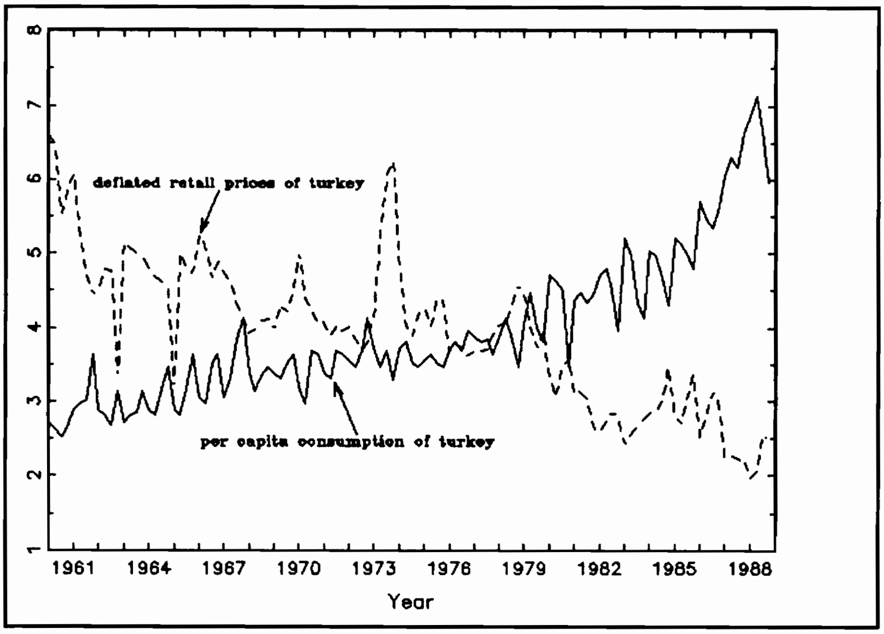

Figure 3.3 Per Capita Consumption and Retail Prices of Turkey

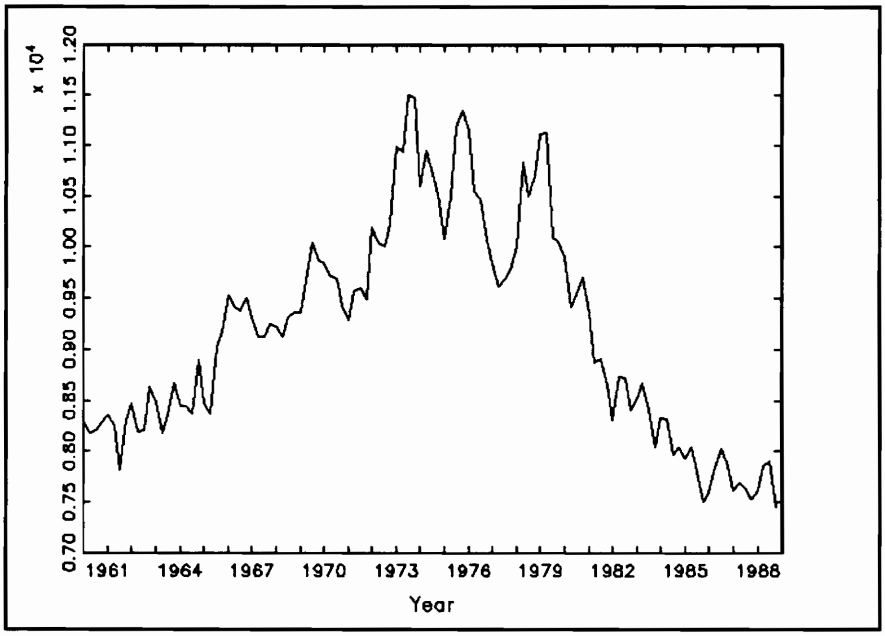

Figure 3.4 Deflated Expenditures on Four Meats

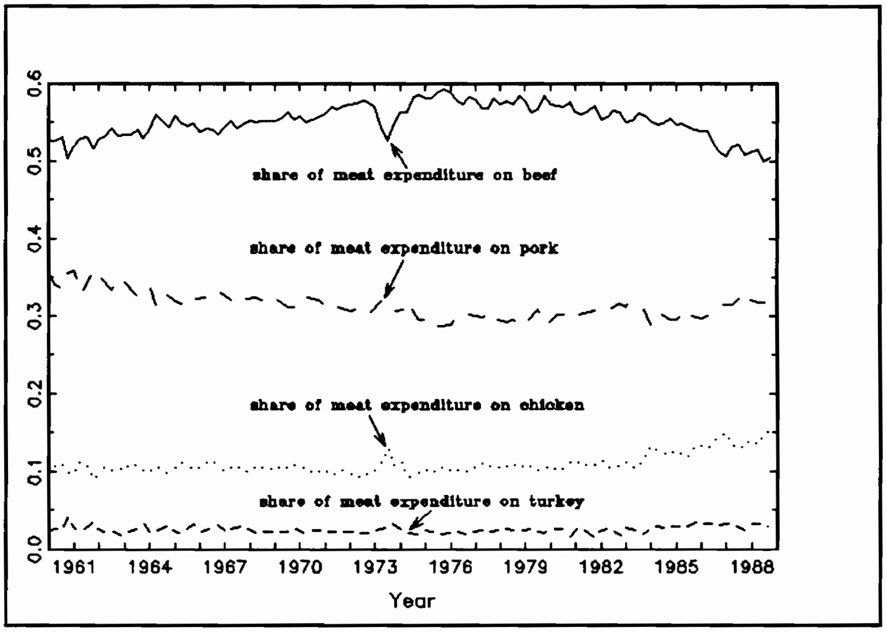

Figure 3.5 Allocation of Shares of Expenditure on 4 Meats

As mentioned earlier, there has been a growing awareness of and interest in health information and health consciousness among consumers. Many researchers have suggested that these changes may have influenced meat purchase decisions. In fact, much of the debate over the issue of structural change has focused on health concerns. A measure of consumer awareness of cholesterol is included in our demand systems in an attempt to directly model structural change and measure the effect of cholesterol concerns on consumption. A proxy variable for consumer awareness of the cholesterol problem is created by identifying articles in the popular press (cited in the Reader's Guide to Periodic Literature) addressing health problems associated with cholesterol in the diet, then summing the distribution (readership) of periodicals in which the articles are published over time. See table 3.1 for the summary statistics of this variable. Figure 3.6 shows how this cholesterol variable has changed over the sample period. This issue did not attract any attention until 1969. The first flow of cholesterol articles occurred between 1969–1973. From 1973–1978, few additional articles appeared. Since 1978, the flow of articles has increased at an increasing rate, perhaps indicating a more widespread concern for the health content of food.

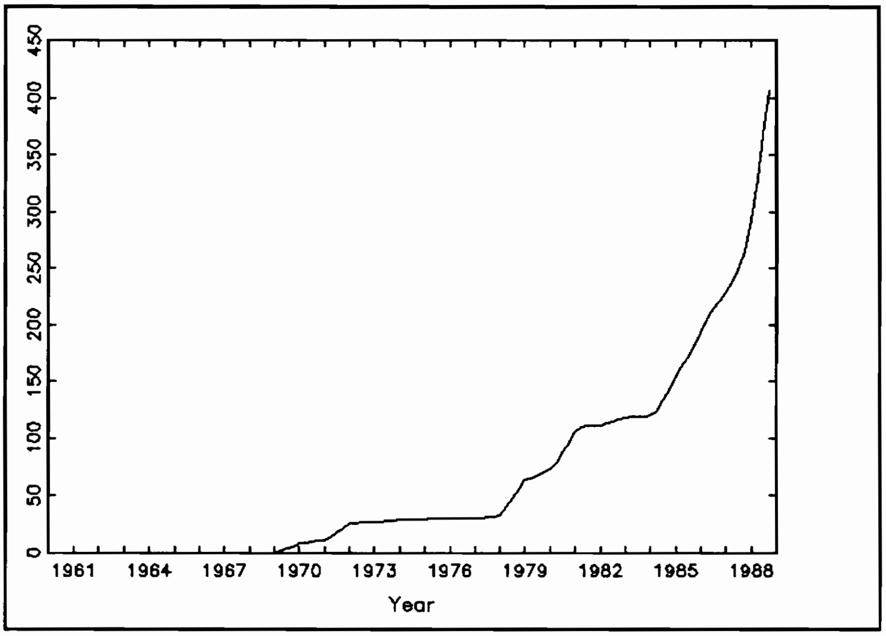

Figure 3.6 The Time Path of the Cholesterol Awareness

The remainder of this chapter proceeds as follows. For each model, the specific functional form initially estimated is presented. Then the results of the tests for statistical adequacy of the model are summarized. If these test results indicate the models are misspecified, an attempt is made to find a statistically adequate model. If a statistically adequate model is found, tests of structural change and tests of the theoretical restrictions discussed in chapter 2 are conducted.

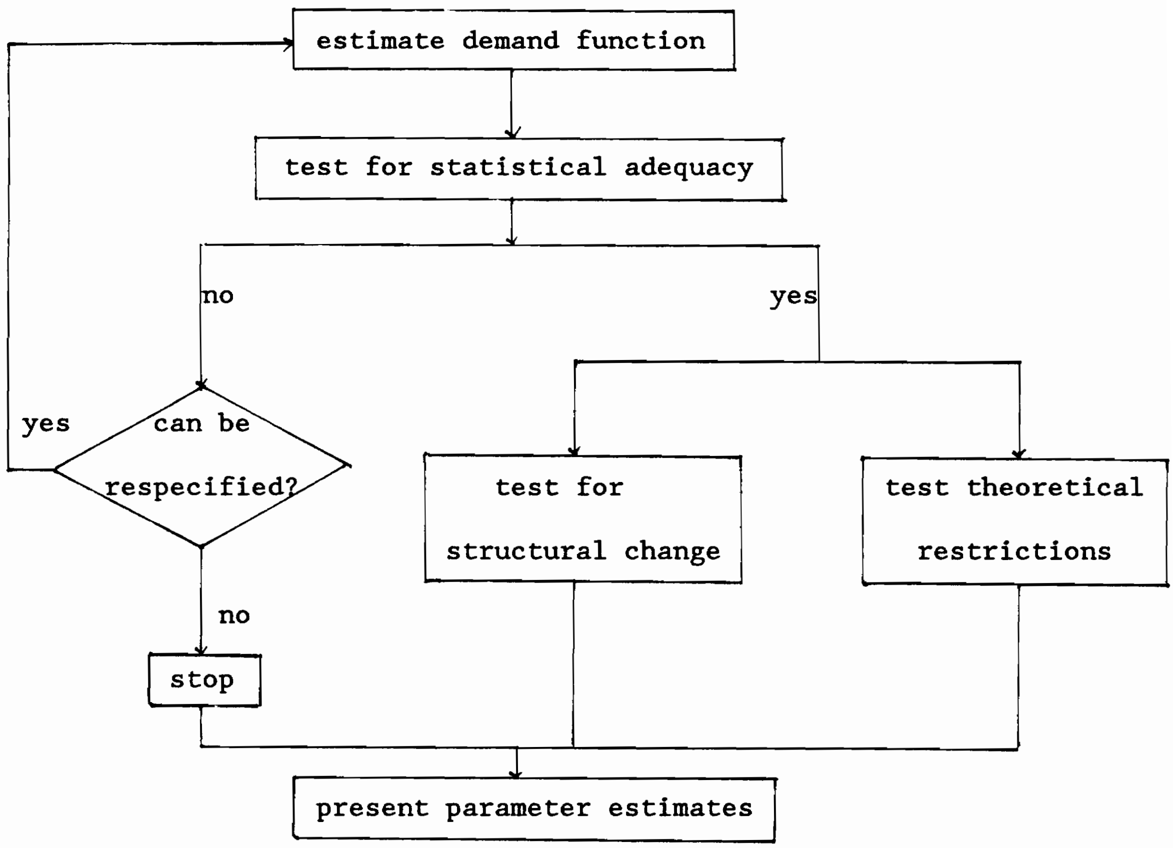

Figure 3.7 Flow Diagram of Estimation and Testing Procedure

Section 3.2 The Linear Demand System

The first model estimated for the linear demand system is the one used by Chavas(1983) and derived in equation (2.31) in chapter 2. Seasonal dummies are added to the system because quarterly data are used. The model is estimated by OLS on an equation by equation basis, and the statistical assumptions described in section 2.3.2 are tested. The initial model estimated is:

$$\text{Model A.I.}\quad (\Delta q_{it}/q_{i,t-1}) = \beta_{i0} + \Sigma_j \epsilon_{ij}(\Delta p_{jt}/p_{j,t-1}) + \eta_i(\Delta M_t/M_{t-1}) + \Sigma_k \alpha_{ik} d_k + e_{it}\ , \qquad i=1,\ldots,4$$

The results of the misspecification tests are summarized in table 3.2.[1] They show that all the statistical assumptions except linearity are violated.

To attempt to solve the problem of autocorrelation, all lagged dependent variables are entered as regressors. In addition to this, the restrictions imposed by the use of percentage changes of continuous variable in A.I are relaxed. The percentage change of a variable is approximately equivalent to the difference between the log variable and log-lagged variable, with the restriction that the coefficient on the log-lagged variable equals negative one. Specifically, the model estimated is:

[1]These tests are explained in detail in section 2.3.2

Model A.II. $\log q_{it} = \beta_{i0} + \Sigma_j \beta_{ij1} \log p_{jt} + \beta_{i2} \log M_t + \Sigma_k \beta_{ik3} d_k$

$$+ \Sigma_j \beta_{ij4} \log p_{jt-1} + \beta_{i5} \log M_{t-1} + \Sigma_j \beta_{ij6} \log q_{jt-1} + e_{it}, \quad i=1,\ldots,4$$

Again, the misspecification tests in table 3.2 show all the statistical assumptions are violated. A possible reason for these violations is that structural change has occurred and that the variable describing this change should be included in the model. Model A.III is identical to A.II except the log of cholesterol serve as a variable to explain structural change. This model includes the logarithm of cholesterol as an intercept shifter and as an interaction variable with all the other independent variables. Thus, all parameters are allowed to change. Model A.III is shown below:

Model A.III. $\log q_{it} = \Gamma_{i0} + \Sigma_j \Gamma_{ij1} \log p_{jt} + \Gamma_{i2} \log M_t + \Sigma_k \Gamma_{ik3} d_k + \Sigma_j \Gamma_{ij4} \log p_{jt-1}$

$$+ \Gamma_{i5} \log M_{t-1} + \Sigma_j \Gamma_{ij6} \log q_{jt-1} + \Sigma_j \Gamma_{ij7} lcllogp_{jt}$$

$$+ \Gamma_{i8} lcllogM_t + \Sigma_k \Gamma_{ik9} lcld_k + \Sigma_j \Gamma_{ij10} lcllogp_{jt-1}$$

$$+ \Gamma_{i11} lcllogM_{t-1} + \Sigma_j \Gamma_{ij12} lcllogq_{jt-1} + \Gamma_{i13} lcl_t$$

$$+ \Gamma_{i14} lcl_{t-1} + e_{it}, \quad i=1,\ldots,4$$

where the variable "lcl" indicates log of the cholesterol and interaction variables are denoted by combining variable names.

The results of the misspecification tests for model A.III (table 3.2) indicate that only the normality and linearity assumptions are violated.

Given that the assumption of linear conditional mean is soundly rejected, it is unclear how we can remedy this problem within the context of this demand system. Consequently, no further attempts to improve this model are made. The only conclusion that can be drawn is the none of these models are statistically adequate. This implies that they do not provide an adequate summary of the data. Consequently, no significance tests of parameters or tests of theoretical restrictions can be conducted because without statistical adequacy, these tests are invalid. For completeness sake, however, the parameter estimates are presented in table 3.3 (model A.I) and Appendix D (models A.II & A.III).

If one ignored the fact that model A.I is not an adequate model of meat demand, the coefficients on the price variables (PB', PP', PC', and PT') would be interpreted as price elasticities, and the coefficient on Y' tells the income elasticity of demand for that commodity. Simply to illustrate the kind of conclusions that could have been drawn if one ignored the statistical issues discussed above, the parameters of this model (A.I) are briefly described.

The results in table 3.3 indicate that all the own-price elasticities are negative as one would expect. Note also that the estimated parameters are large relative to their standard errors; without examining statistical adequacy carefully one might conclude that the model results are quite reasonable. To interpret the cross-price elasticities in the table, recall that a positive cross-price elasticity implies the goods are substitutes while a negative sign indicates the goods are complements. For example, the cross-price elasticity between the quantity of beef and the price of pork is 0.173, which implies that the two commodities are substitutes. A 10% increase in the price of pork leads to a 1.73% increase in the quantity of beef consumed, ceteris paribus.

An income elasticity indicates how much the quantity of a commodity will change in response to a marginal change in total income. The income elasticities in table 3.3 indicate that beef, chicken and turkey are normal (luxury) goods and pork is an inferior good. The high income elasticity of turkey and chicken are somewhat suspect and that for pork is unreasonable as the income elasticities for food items are generally positive and less than one.

In summary, no statistically adequate model is found for the linear demand system, consequently no tests of structural change and restrictions are made. Even though no statistically adequate model is obtained, the parameters of model A.I are interpreted as if they were theoretically meaningful. This exercise just illustrates the kind of erroneous conclusions that may have been made if statistical issues were ignored. The only conclusion that is drawn at this point is that the linear demand system estimated here does not adequately summarize the data on meat demand used in this study. More detailed discussion will be presented in Chapter 4.

Table 3.2 Misspecification tests for models A.I, A.II, and A.III

	Model A.I	Model A.II	Model A.III
Normality	$\tau_{1s}(20)=49.2086$ p=.000287 $\tau_{1k}(1)=35.5454$ p=0	$\tau_{1s}(20)=44.2596$ p=.001389 $\tau_{1k}(1)=17.7489$ p=.000025	$\tau_{1s}(20)=39.4237$ p=.005903 $\tau_{1k}(1)=9.0524$ p=.002624
Linearity	$\tau_2(40)=49.1309$ p=.152579	$\tau_2(40)=185.9167$ p=0	$\tau_2(40)=99.4354$ p=.000001
Homoskedasticity	$\tau_3(100)=182.7176$ p=.000001	$\tau_3(100)=158.4021$ p=.00018	$\tau_3(100)=105.1018$ p=.343932
No-Autocorrelation	$\tau_4(16)=82.0844$ p=0	$\tau_4(16)=50.4392$ p=.00002	$\tau_4(16)=22.3056$ p=.133594
Parameter Time Invariance	ok	bad	ok

Table 3.3 The parameter estimates for model A.I[a]

Independent Variables	Dependent variables: Quantity of Beef(QB')	Pork(QP')	Chicken(QC')	Turkey(QT')
CONST	-0.002674	-0.059353	0.000745	-2.978407
	(0.007135)	(0.009456)	(0.010254)	(0.158211)
PB'	-0.515725	0.593539	-0.208792	2.030140
	(0.093817)	(0.124337)	(0.134824)	(2.080203)
PP'	0.172953	-0.763530	0.246320	0.106959
	(0.064288)	(0.085201)	(0.092387)	(1.425450)
PC'	-0.054655	-0.051090	-0.247747	-0.203316
	(0.054257)	(0.071907)	(0.077972)	(1.203027)
PT'	-0.001553	-0.009508	-0.039553	-2.032433
	(0.025101)	(0.033267)	(0.036073)	(0.556570)
Y'	0.227798	-0.167610	1.044139	9.753094
	(0.284118)	(0.376545)	(0.408304)	(6.299737)
D1	0.005447	-0.003779	0.085608	2.931447
	(0.007845)	(0.010397)	(0.011274)	(0.173945)
D2	0.029595	0.074647	-0.016892	3.163625
	(0.008222)	(0.010896)	(0.011815)	(0.182296)
D3	-0.025291	0.167333	-0.116675	3.363568
	(0.008690)	(0.011517)	(0.012488)	(0.192682)
R^2 :	0.437	0.814	0.754	0.815

[a]The variables reported in the table are defined as follows:

$QB'=(\Delta q_t/q_{t-1})$ for beef, $QP'=(\Delta q_t/q_{t-1})$ for pork,
$QC'=(\Delta q_t/q_{t-1})$ for chicken, $QT'=(\Delta q_t/q_{t-1})$ for turkey,
$PB'=(\Delta p_t/p_{t-1})$ for beef, $PP'=(\Delta p_t/p_{t-1})$ for pork,
$PC'=(\Delta p_t/p_{t-1})$ for chicken, $PT'=(\Delta p_t/p_{t-1})$ for turkey,
$Y'=(\Delta M_t/M_{t-1})$ for expenditure, Di=seasonal dummy variables.

Section 3.3 The Inverse Demand System

In this section, an inverse demand system is used to model the demand for meats. Model B.I is derived directly from equation (2.33) and is identical to that used by Huang. The data, however, are different from those used by Huang since his demand system included many food items in addition to meats. Again, seasonal dummies are included in each equation as quarterly data are used, and the model is estimated by OLS on an equation by equation basis. The statistical assumptions described in section 2.3.2 are tested. The specific model estimated (model B.I) is presented as follows:

Model B.I. $$dr_{it}/r = \Sigma_j \delta_{ij}{}^c (dq_{jt}{}^*/q^*) + \mu_i (dk_t/k) + \Sigma_k \alpha_{ik} d_k + e_{it}$$

$$i=1,\ldots,4$$

The results of the misspecification tests for this inverse demand system are summarized in table 3.4. The test results indicate that almost all the statistical assumptions are violated. Since the no-autocorrelation assumption appears to be violated, we propose to remedy this problem first. As in the linear demand system, model B.II relaxes the log difference assumption and incorporates all the lagged dependent variables in each equation. The second model estimated is summarized as follows:

Model B.II. $$\log r_{it} = \beta_{i0} + \Sigma_j \beta_{ij1} \log q_{jt} + \beta_{i2} \log k_t + \Sigma_k \beta_{ik3} d_k + \Sigma_j \beta_{ij4} \log q_{jt-1} + \beta_{i5} \log k_{t-1} + \Sigma_j \beta_{ij6} \log r_{jt-1} + e_{it},$$

$$i=1,\ldots,4$$

The misspecification tests (as shown in table 3.4) indicate that all the statistical assumptions are violated expect linearity and autocorrelation. The plots of the recursive least square estimates indicate that the assumption of parameter time invariance is suspect. Again, this might mean that structural change occurred. Therefore, the cholesterol variable is incorporated into the model. As in the linear demand system, it is assumed that all parameters are affected by the structural change. Consequently, model B.III is identical to model B.II except that log of cholesterol is included and used to model the structural change. Model B.III is written as:

Model B.III. $$\begin{aligned} \text{logr}_{it} = {} & \Gamma_{i0} + \Sigma_j \Gamma_{ij1}\text{logq}_{jt} + \Gamma_{i2}\text{logk}_t + \Sigma_k \Gamma_{ik3} d_k + \Sigma_j \Gamma_{ij4}\text{logq}_{jt-1} \\ & + \Gamma_{i5}\text{logk}_{t-1} + \Sigma_j \Gamma_{ij6}\text{logr}_{jt-1} + \Sigma_j \Gamma_{ij7}\text{lcllogq}_{jt} \\ & + \Gamma_{i8}\text{lcllogk}_t + \Sigma_k \Gamma_{ik9}\text{lcld}_k + \Sigma_j \Gamma_{ij10}\text{lcllogq}_{jt-1} \\ & + \Gamma_{i11}\text{lcllogk}_{t-1} + \Sigma_j \Gamma_{ij12}\text{lcllogr}_{jt-1} + \Gamma_{i13}\text{lcl}_t \\ & + \Gamma_{i14}\text{lcl}_{t-1} + e_{it}, \qquad i=1,\ldots,4 \end{aligned}$$

Again, the lcl variable represents the log of the cholesterol. The results of the misspecification tests for model B.III show that normality and homoskedasticity are violated.

Given that only homoskedasticity and normality are violated, it may be that $y|x$ is not normally distributed but is some other member of the elliptical family of distributions.[2] All the distributions in this

[2]The elliptical family includes distributions such as student-t, cauchy, etc.

family have a linear conditional mean but a heteroskedastic variance. The exercise of modelling this system of demand equations under alternate distributional assumptions is left for future research.

Because none of the models estimated provide an adequate summary of the data, no tests of the theoretical restrictions or structural change can be conducted.

Table 3.5 contains the estimated parameters for model B.I where the coefficients on the quantity variables (QB', QP', QC', and QT') reflect compensated price flexibilities and the coefficients of scale variables (S') represent scale flexibilities. Just as with the linear demand system, the estimated parameters of model B.I are discussed despite the fact that this model is not statistically adequate. The estimates are discussed merely to indicate the type of conclusions that could have been drawn if the statistical issues discussed above were ignored. (The parameter estimates of models B.II and B.III are presented in appendix D but not discussed.)

From table 3.5, it is obvious that own-price flexibilities are negative as might be expected. The cross-price flexibilities indicate substitution if the sign is negative and complements if the sign is positive. For example, the compensated cross-price flexibility between the price of chicken and the quantity of beef is -0.022, which implies that the two commodities are substitutes. Specifically the coefficient indicates that a 10% increase in the quantity of beef consumed will lead to a 0.22% decrease in the price of chicken, ceteris paribus. On the other hand, the compensated cross-price flexibility between the price of beef and quantity of pork is 0.22, indicating that an increase of the quantity of pork by 10% will cause the price of beef to increase by 2.2% because of their complementary relationship.

The scale flexibilities indicate the potential response of commodity price to a proportionate increase in the quantities of all commodities. For example, the scale flexibility for beef is -0.927, which indicates that a proportionate increase in all commodities by 10% will decrease the price of beef by 9.27%. All the estimated scale flexibilities, except for pork, are negative as expected.

In summary, none of the inverse demand models estimated are found to be statistically adequate. Therefore no further tests for structural change and theoretical restrictions are conducted. Despite the fact that the parameters of model B.I are given some theoretical interpretation, this exercise is strictly academic and undertaken to illustrate the type of conclusions that could be drawn from estimating a system of demand equations such as this but ignoring some relevant statistical issues.

Table 3.4 Misspecification tests for models B.I, B.II, and B.III

	Model B.I	Model B.II	Model B.III
Normality	$\tau_{1s}(20)=97.3795$ $p=0$ $\tau_{1k}(1)=143.9158$ $p=0$	$\tau_{1s}(20)=86.211$ $p=0$ $\tau_{1k}(1)=161.6872$ $p=0$	$\tau_{1s}(20)=43.3596$ $p=.001832$ $\tau_{1k}(1)=74.7829$ $p=0$
Linearity	$\tau_2(40)=144.0809$ $p=0$	$\tau_2(40)=50.1261$ $p=.130976$	$\tau_2(40)=44.3364$ $p=.293801$
Homoskedasticity	$\tau_3(100)=198.3578$ $p=0$	$\tau_3(100)=139.0399$ $p=.006007$	$\tau_3(100)=178.3077$ $p=.000002$
No-Autocorrelation	$\tau_4(16)=35.1076$ $p=.003842$	$\tau_4(16)=20.723$ $p=.189404$	$\tau_4(16)=6.3903$ $p=.983304$
Parameter Time Invariance	ok	marginal	ok

Table 3.5 The parameter estimates for model B.I[b]

Independent Variables	Dependent variables: price of			
	Beef(PB')	Pork(PP')	Chicken(PC')	Turkey(PT')
CONST	0.007880	-0.013193	-0.017987	-0.369077
	(0.008042)	(0.012561)	(0.027293)	(0.058445)
QB'	-0.219318	-0.240803	-0.022522	2.651490
	(0.122674)	(0.191612)	(0.416355)	(0.891563)
QP'	0.218608	-0.735833	-0.156480	1.036073
	(0.072222)	(0.112808)	(0.245120)	(0.524890)
QC'	0.105865	-0.094632	-0.358971	0.039829
	(0.035938)	(0.056134)	(0.121974)	(0.261191)
QT'	0.002340	-0.006100	0.000918	-0.007836
	(0.002823)	(0.004410)	(0.009582)	(0.020518)
S'	-0.926769	0.007749	-1.130783	-5.877411
	(0.218385)	(0.341108)	(0.741195)	(1.587162)
D1	0.006189	-0.026375	0.041905	0.434156
	(0.010272)	(0.016045)	(0.034863)	(0.074655)
D2	-0.012689	0.012615	0.031530	0.424830
	(0.010758)	(0.016804)	(0.036513)	(0.078187)
D3	-0.026177	0.038263	-0.019665	0.579887
	(0.013483)	(0.021059)	(0.045760)	(0.097988)
R^2 :	0.920	0.846	0.610	0.292

[b]The variables reported in the table are defined as follows:

$PB'=(\Delta p_t/p_{t-1})$ for beef, $PP'=(\Delta p_t/p_{t-1})$ for pork,
$PC'=(\Delta p_t/p_{t-1})$ for chicken, $PT'=(\Delta p_t/p_{t-1})$ for turkey,
$QB'=(\Delta q^*_t/q^*_{t-1})$ for beef, $QP'=(\Delta q^*_t/q^*_{t-1})$ for pork,
$QC'=(\Delta q^*_t/q^*_{t-1})$ for chicken, $QT'=(\Delta q^*_t/q^*_{t-1})$ for turkey,
$S'=(\Delta k_t/k_{t-1})$ for scale, Di=seasonal dummy variables.

Section 3.4 Almost Ideal Demand System

The final functional form used in this study is an AIDS model. Model C.I is the one discussed in equation (2.44) and used by Moschini and Meilke except the log of the cholesterol variable is used to model structural change. As in the previous two systems, all parameters are assumed to change so a full set of interaction terms are included. The model is estimated by OLS on an equation by equation basis and the statistical assumptions described in section 2.3.2 are tested. The initial model estimated is:

Model C.I. $$Dw_{it} = \beta_0 + \Sigma_j\beta_{ij}Dp_{jt} + \beta_iDx_t + \Sigma_k\alpha_{ik}Dd_k + \Sigma_j\theta_{ij}Dlcl_tp_{jt} + \theta_iDlcl_tx_t + \Sigma_k\Gamma_{ik}Dlcl_td_k + \tau_iDlcl_t + e_{it}, \quad i=1,\ldots,3$$

where Dw_{it} represents the first difference of share of meat expenditure on commodity i at time t, Dp_{jt} represents the first difference of the log of the price of commodity j at time t, etc. Note that only three equations are estimated in the AIDS instead of four in previous systems. The reason for omitting one equation is to prevent the problem of singular error covariance matrix of disturbances, because shares are used as dependent variables instead of a quantities in the AIDS models.[3]

[3]Because the equations are estimated using OLS, all four equations could be estimated. However, all of the misspecification tests involve an estimate of the variance-covariance matrix of the 'system' which is singular unless one share is deleted.

Tests of the underlying statistical assumptions of the system are conducted. The results are summarized in table 3.6. They indicate that all the statistical assumptions are violated except skewness and linearity. Following the same argument presented before, the problem of autocorrelation is remedied first. Therefore, the restriction of minus one on the coefficients of the lagged variables is relaxed. In addition, all the lagged dependent variables are included in each equation. This is referred to as model C.II:

Model C.II. $w_{it} = \beta_0 + \Sigma_j\beta_{ij1}p_{jt} + \beta_{i2}x_t + \Sigma_k\beta_{ik3}d_k + \Sigma_j\beta_{ij4}lcl_tp_{jt} + \beta_{i5}lcl_tx_t$

$$+ \Sigma_k\beta_{ik6}lcl_td_k + \Sigma_j\beta_{ij7}w_{jt-1} + \Sigma_j\beta_{ij8}p_{jt-1} + \beta_{i9}x_{t-1}$$

$$+ \Sigma_j\beta_{ij10}lcl_{t-1}p_{jt-1} + \beta_{i11}lcl_{t-1}x_{t-1} + \Sigma_j\beta_{ij12}lcl_{t-1}w_{jt-1}$$

$$+ \beta_{i13}lcl_t + \beta_{i14}lcl_{t-1} + e_{it}\ , \quad i=1,\ldots,3$$

The misspecification tests (table 3.6) show that all the assumptions are violated except no-autocorrelation. Since this general model cannot provide an adequate summary of the data, and there is no way to improve the model, no further attempt to use this model is made.

None of these models are statistically adequate.[4] Consequently, no tests of theoretical restrictions and of structural change can be conducted. The parameter estimates for models C.I and C.II are presented in Appendix D.

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[4]The AIDS models are also estimated using a Farley-Hinich path and the level of the cholesterol variable to model the structural change. Similar results are obtained—none of the models was found to be statistically adequate.

The results from estimation of these three systems are troubling in the sense that the demand systems are used to examine the demand for meats and to address the issue of structural change. Yet, none of them are statistically adequate. Without statistical adequacy, no tests of theory and of the significance of the parameter estimates can be conducted. Thus, really nothing can be said about the demand for meats based on these results.

While these findings suggest that some of the results in the literature may be suspect, it is important to note that none of the studies in the literature are replicated exactly. Instead, the most commonly used data are employed to estimate three demand systems popular in the literature. These results cast doubt on the validity of many of these other studies.

Moschini and Meilke provided the exact data used in their paper "Modelling the Pattern of Structural Change in U.S. Meat Demand". Because of this, their data can be used to replicate their results and examine if their models are statistically adequate.

Table 3.6 Misspecification tests for models C.I and C.II

	Model C.I	Model C.II
Normality	$\tau_{1s}(10)=13.792459$ p=.182670 $\tau_{1k}(1)=8.6967$ p=.003188	$\tau_{1s}(10)=23.9754$ p=.000186 $\tau_{1k}(1)=27.8023$ p=0
Linearity	$\tau_2(18)=26.4971$ p=.088923	$\tau_2(18)=97.9070$ p=0
Homoskedasticity	$\tau_3(36)=79.3409$ p=.000042	$\tau_3(36)=71.6638$ p=.000373
No-Autocorrelation	$\tau_4(9)=18.7589$ p=.027323	$\tau_4(9)=4.3934$ p=.883665
Parameter Time Invariance	bad	bad

Section 3.5 Re-examining the Results of Moschini and Meilke

The AIDS models estimated by Moschini and Meilke are now re-estimated. Recall that while the Moschini and Meilke data incorporated the same data as that used above for beef, pork, and chicken, they included fish consumption rather than turkey. Personal consumption expenditure for fish on a quarterly basis are obtained from unpublished U.S. Department of Commerce (USDC) data, and the CPI for fish from USDC is used to deflate fish prices. Because fish are included rather than turkey, the total expenditure and shares of expenditures on the four meats differs from those used in the previous AIDS systems (models C.I and C.II).

Four means of modelling structural change are employed to estimate AIDS models using this data set. Two were employed by Moschini and Meilke. These are the gradual shift spline path (see chapter two) and the Farley-Hinich (time trend) path. In addition, the cholesterol variable is used in both logarithm and level form. The estimation and respecification procedures are similar to that employed above. Specifically, the models estimated can be written as:

Model D.I. $$Dw_{it} = \beta_0 + \Sigma_j\beta_{ij}Dp_{jt} + \beta_iDx_t + \Sigma_k\alpha_{ik}Dd_k + \Sigma_j\theta_{ij}Dh_tp_{jt} + \theta_iDh_tx_t + \Sigma_k\Gamma_{ik}Dh_td_k + \tau_iDh_t + e_{it}, \quad i=1,\ldots,3$$

where h_t is first defined as the gradual-shift spline path defined by Moschini and Meilke, then the Farley-Hinich path, and finally by the logarighm and level of the cholesterol variable. Following Moschini and Meilke, for the gradual-shift spline model (spline), the period of the gradual shift is assumed to begin in 1975(4) and end in 1976(3). In the Farley-Hinich model (fh) h_t is defined to be equal to t/T, where t is the accumulating numbers of periods and T is the total number of periods. Thus, it assumes that the structural change is smooth and continual.

To be consistent with Moschini and Meilke, the first difference AIDS formulation is specified with homogeneity already implicitly imposed as the prices of beef, pork and chicken are all deflated by the price of fish. Consequently, only three prices are included in each equation.

In all four specifications of the model (spline, fh, cholesterol, and log of cholesterol), model D.I seriously violates the no-autocorrelation assumption, among others. Consequently, the models are re-estimated relaxing the restriction of a minus one coefficient on all the lagged variables and by including all lagged dependent variables in each equation. Specifically, the reformulation considered next (D.II) is:

Model D.II. $$w_{it} = \beta_0 + \Sigma_j\beta_{ij1}p_{jt} + \beta_{i2}x_t + \Sigma_k\beta_{ik3}d_k + \Sigma_j\beta_{ij4}h_tp_{jt} + \beta_{i5}h_tx_t + \Sigma_k\beta_{ik6}h_td_k + \Sigma_j\beta_{ij7}w_{jt-1} + \Sigma_j\beta_{ij8}p_{jt-1} + \beta_{i9}x_{t-1} + \Sigma_j\beta_{ij10}h_{t-1}p_{jt-1} + \beta_{i11}h_{t-1}x_{t-1} + \Sigma_j\beta_{ij12}h_{t-1}w_{jt-1} + \beta_{i13}h_t + \beta_{i14}h_{t-1} + e_{it}, \qquad i=1,\ldots,3$$

All the underlying statistical assumptions of model D.II are accepted, indicating this is a statistically adequate model. Tables 3.7 and 3.8 report the results from the misspecification tests for each of these models. While the log cholesterol model (lchol) appears to be the best model in terms of statistical adequacy, the other three models, particularly the level cholesterol model (chol), can also be considered as marginally statistically adequate. Consequently, they can be used to test any theoretical assumptions of interest and/or structural change. (The parameter estimates from all four specifications for model D.II are presented in appendix D.)

One potential theoretical model nested within model D.II is a partial adjustment/habit persistence type of model (with structural change). This model includes all the static variables as well as the lagged <u>share</u> variables (and share interactions). Specifically, the restricted model estimated is:

Model D.III. $$w_{it} = \beta_0 + \Sigma_j\beta_{ij1}p_{jt} + \beta_{i2}x_t + \Sigma_k\beta_{ik3}d_k + \Sigma_j\beta_{ij4}h_tp_{jt} + \beta_{i5}h_tx_t + \Sigma_k\beta_{ik6}h_td_k + \Sigma_j\beta_{ij7}w_{jt-1} + \Sigma_j\beta_{ij12}h_{t-1}w_{jt-1} + \beta_{i13}h_t + e_{it}$$

$$i=1,\ldots,3$$

Unfortunately, in all four specifications likelihood ratio tests indicate that these restrictions are rejected. Further, the misspecification tests of the restricted models indicate that the assumption of no-autocorrelation is violated in all four instances. Consequently, this partial adjustment type of model can be pursued no further. No other theoretical model that includes lagged variables could be found and thus, no further "theoretical" tests are conducted.

Even though no other "theoretical restrictions" could be thought of to test using the statistically adequate model, it is possible to test for structural change. To test for structural change, model D.II is designated the unrestricted model, and the restricted model is a model which excludes all the structural change variables. Specifically, the restricted model (D.IV) is:

$$\text{Model D.IV.}\quad w_{it} = \beta_0 + \Sigma_j\beta_{ij1}p_{jt} + \beta_{i2}x_t + \Sigma_k\beta_{ik3}d_k + \Sigma_j\beta_{ij7}w_{jt-1} + \Sigma_j\beta_{ij8}p_{jt-1} + \beta_{i9}x_{t-1} + e_{it}, \quad i=1,..,3$$

The null hypothesis is that the coefficients on all the variables which incorporate the structural change variable equal zero. In all four specifications, the results from the likelihood ratio tests suggest that structural change has occurred. The specific test statistics are 111.11 for the spline, 155.28 for the fh, 152.09 for chol, and 110.97 for lchol (critical value $\chi^2(48)=64$). Given that the model incorporating the logarithm of the cholesterol variable seemed to provide the best (most adequate) summary of the data, the conclusion can be drawn not only that structural change has occurred but that consumers' concern for cholesterol may be a key driving factor in the changing preferences.

Thus, despite the fact that a statistically adequate model for the three different demand systems (linear, inverse demand, and AIDS) cannot be found when modelling the demand for beef, pork, chicken and turkey, a dynamic AIDS system can be used to model the demand for beef, pork, chicken and fish. The three demand systems are not able to capture the essence of the beef, pork, chicken and turkey data. The results using Moschini and Meilke's data suggest structural change may have occurred. In the next chapter, the implications of these findings are discussed and some conclusions are drawn.

Table 3.7 Misspecification tests for models D.II(spline) and D.II(fh)

	Model D.II(spline)	Model D.II(fh)
Normality	$\tau_{1s}(10)=16.841$ $p=.077956$ $\tau_{1k}(1)=5.4164$ $p=.019949$	$\tau_{1s}(10)=9.6669$ $p=.470187$ $\tau_{1k}(1)=.0261$ $p=.871537$
Linearity	$\tau_2(18)=26.2421$ $p=.09435$	$\tau_2(18)=33.7847$ $p=.013389$
Homoskedasticity	$\tau_3(36)=51.4257$ $p=.04602$	$\tau_3(36)=37.419$ $p=.4038$
No-Autocorrelation	$\tau_4(9)=12.8648$ $p=.168822$	$\tau_4(9)=6.0863$ $p=.731251$
Parameter Time Invariance	ok	ok

Table 3.8 Misspecification tests for models D.II(chol) and D.II(lchol)

	Model D.II(chol)	Model D.II(lchol)
Normality	$\tau_{1s}(10)=14.9013$ p=.135703 $\tau_{1k}(1)=.0285$ p=.865829	$\tau_{1s}(10)=15.85$ p=.104005 $\tau_{1k}(1)=1.2213$ p=.269105
Linearity	$\tau_2(18)=29.4102$ p=.043591	$\tau_2(18)=25.9199$ p=.101604
Homoskedasticity	$\tau_3(36)=36.2564$ p=.456695	$\tau_3(36)=46.4238$ p=.114384
No-Autocorrelation	$\tau_4(9)=5.4102$ p=.797189	$\tau_4(9)=3.7296$ p=.928293
Parameter Time Invariance	ok	ok

Chapter 4

Summary and Conclusions

In this thesis, three approaches to consumer demand theory are employed. These approaches are applied to the study of demand for meats in the United States. Special attention is paid to concern for cholesterol and its effect on meat demands. The dynamics of adjustment in consumption to changing prices and income are also examined in different ways. Throughout estimation, the models are evaluated for statistical adequacy, and the relationship between testing for structural change and adequacy is exploited.

This study uses a linear demand system, an inverse demand system, and an AIDS. These three types of systems have been used previously to study meat demands. The study does not replicate any previous studies but examines structural change with commonly used functional forms and data. For the linear demand system, three types of models are tested. These are an original (restricted) model, a general (unrestricted) model, and a general model with the log of the cholesterol variable to model structural change. None of these three models is statistically adequate. Because of this, tests of theory and for structural change can not be conducted.

The three variations of the inverse demand system yield the same results. The assumptions of normality, linearity, homoskedasticity and absence of autocorrelation are violated in most cases.

The AIDS models include an original restricted model, a general dynamic model including lags on all prices and lags of all meat shares, and a general model including only lags of meat shares. A log of the cholesterol variable is used to model structural change. None of the models is statistically adequate when using the beef, pork, chicken and turkey disappearance data.

Because of this, the AIDS models are re-estimated using a data set provided by Moschini and Meilke which includes fish consumption and not turkey. The four meats in this second data set are beef, pork, chicken and fish. In addition to the log of the cholesterol variable, a spline path, a Farley-Hinich path, and the unlogged cholesterol variable are used to model structural change with these data. A restricted model (first differences in shares explained by first differences in independent variables), and a general dynamic model (with lagged shares of all meats and lags of prices explaining levels of shares) are estimated. Full interaction between the structural change variables and the independent variables is allowed.

The general dynamic models are statistically adequate using any of the four means of modeling structural change. Restricted models are tested to see if the restrictions from economic theory can be imposed. Although some models are statistically adequate when lagged variables are deleted, the likelihood ratio tests show the general model is preferred. Lacking methods to impose theoretical restrictions on the lagged variables found in the general models, it is not possible to conduct further tests of these restrictions. A model which excludes all the structural change variables is used as a restricted model to test for structural change, and the results indicate structural change has occurred in the demand for meats.

Structural change is found to occur when AIDS models with data set including fish consumption is used. Further, examination shows that the dynamic AIDS models with the log of the cholesterol variable is preferred to the other means of modeling structural change. This indicates that health concerns appear to be an important factor in the meat purchase decision. It also indicates that the cholesterol variable is consistent with, and helping to explain, the data. In fact, the cholesterol is very much like a time trend in the models, and any trending variable might do the trick; for example, spline and Farley-Hinich paths work almost as well in the models. In contrast to these paths, the log of the cholesterol variable continues to trend upward. Accordingly, consumers are still learning about the effects of cholesterol and are continuing to change their behavior in response to this knowledge. It is doubtful that any define conclusions can be made with these data. Micro consumer data are needed to reach these conclusions.

No statistically adequate model can be found using three common functional forms with the standard data set (the one that includes turkey instead of fish). Neither structural change nor theoretical restrictions can be tested with these inadequate models. By using the data that include fish consumption instead of turkey, dynamic AIDS models are found to be statistically adequate. Because of this, it is suspected that the turkey data are causing the problems. Tests for theory cannot be conducted even with fish consumption data. Because the theoretical restrictions cannot be imposed, the data do not appear to be consistent with the economic theory.

It is difficult to determine the causes of the problem of lack of statistical adequacy in the case of the data set that includes turkey. Some of these causes are discussed here:

1) Data problems.

There are two dimensions of this problem. First, the data used in this study are aggregate disappearance data. These data are the residual component of the commodity supply–utilization table, and represent the disappearance of meat into the marketing system. This method of computation relegates to the meat supply all residual uses for which data are not available, such as miscellaneous nonfood uses, stock changes at retail and consumer levels, and sampling and measurement errors accumulated in the estimation of other components of the balance sheet (Putnam, 1990).

This method can overstate actual consumption because it includes spoilage and waste accumulated through the marketing system and in the home. An example of overstated human consumption is an increasing proportion of the total chicken supply is going into pet foods but is still counted in disappearance data (Putnam, 1990). In contrast, the lack of reliable estimates of game fish supplies means that fish consumption is likely to be understated. Traditional approaches which regress wholesale production data on retail prices and income may result in estimates of retail demand elasticities that are inconsistent.

Second, the data used are highly aggregated, yet the theoretical model is based on the theory of individual demand. Whether these data can be reconciled with individual preferences is a matter of question.

In order to reconcile market demand with individual theory, the individual demands must satisfy either exact linear or non-linear aggregation. Exact linear aggregation means that Engel curves should be linear and have the same slope for each individual. The assumption of linear Engel curves is not plausible for very disaggregated commodity classifications. Linearity might be a satisfactory assumption for broadly defined composites of goods.

Exact non-linear aggregation[1] allows nonlinear Engel curves at the price of introducing representative rather than average expenditures. For exact non-linear aggregation, provided the distribution of expenditures among the population and the demographic composition of household are constant, aggregate expenditure patterns can be related to average expenditure without error. But this is rarely the case. Deaton and Muellbauer (1980) showed that a constant expenditure distribution is not enough for the perfect aggregation of utility maximizing consumers.

The AIDS model used in this study allows non-linear and consistent aggregation over consumers. The assumptions, however, that income

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[1]For exact nonlinear aggregation, the market pattern of demand can be thought of as being derived from the behavior of a single representative individual with an endowed expenditure, that is, representative of market expenditures. It is assumed that the average aggregate budget share depends on prices and a representative level of total expenditure.

distributions and demographic compositions are static are inconsistent with reality. Thus even AIDS imposes restrictive conditions on preferences when relating aggregate expenditure patterns to average expenditures. The use of highly aggregated data for the linear and inverse demand systems is clearly restrictive.

2) Model assumptions

There are two aspects to the problem of model assumptions. The first one relates to assumptions about consumer behavior. Weak separability between meats and other commodities is frequently assumed in demand studies and is used in this study. This is a rather strong assumption which leads to the modelling of meat demands as a function of prices of meats and expenditure on meats only (this assumption is made in the three demand systems used). In reality, the prices or quantities of other commodities may affect the decisions to purchase meats in a more general fashion than just by influencing total meat expenditures. These prices and quantities should be taken into consideration when modeling the allocation of meat expenditures. A more reasonable assumption might be to assume weak separability between groceries and all other commodities. The data requirements for such a study are large, but improvement in the plausibility of the assumptions may justify the modeling effort (Huang, 1988).

The second model assumption problem is related to functional form. Chavas (1986) states that the use of alternative specifications of demand functions (ie., more flexible functional forms) is likely to provide little or no insights to the nature of the structural changes.

The nature of a preference shift can be characterized by its bias. When using duality relationships, the bias in preference shift might not be identified because there may exist more than one combination of bias and price substitution effects that can rationalize consumer behavior (Chavas, 1986). Without priori information about the nature of the preference shift, the empirical results are expected to vary depending on the model specification, ie., the choice of a function form. Therefore, prior information about possible sources of preference shifts is needed before a functional form is chosen. In this study, a cholesterol variable is used to model this preference shift, and is significant in explaining the structural change of meat demand. Thus, Chavas' concern about the identification of structural change and price shifts is largely unjustified.

Since the USDA food disappearance data are the only source of time series data on food availability in the United States, the above discussion has some serious negative implications for studies of meat demands. Without examining statistical adequacy, the validity of subsequent hypothesis tests is suspect. A careful examination of the model assumptions is necessary prior to deriving policy implications.

With more general models, ie., those not employing the weak separability assumption, adequacy still needs to be tested, of course. Future studies should use a wider range of food categories to make the assumptions of weak separability more plausible. A functional form which allows non-linear aggregation over consumers is preferred (in this study, the AIDS model allows non-linear aggregation, but the other two do not). All variables which may affect meat disappearance must be taken into consideration during the model estimation. For example, family structure and the distribution of income should be included.

In conclusion, this thesis provides a framework for modeling and testing for structural change. When applied to meat disappearance data and the demand for meat, the framework is useful in separating statistical issues from theoretical issues. Structural change appears to have occurred, and concern for cholesterol helps explain it. The study shows that these data are extremely difficult to model, and that any use of them should be accompanied by close examination of the statistical assumptions. The results raise suspicions about whether previous studies paid attention to the statistical adequacy of the models, a critical requirement for testing hypothesis within the models and testing for structural change. Further research needs to be careful to examine problems possibly causing model failure. Modelers should carefully consider data generation, aggregation, and the assumptions made, etc. Some variables which may cause the structural change of meat demand should be explored in further studies.

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Appendix A

Table A.1 Summary of Studies on Structural Change in the Demand for Meats in the United States.

Author(s)		Data / Meats
Braschler (1983)		Annual 1950–1982 / beef, pork
	Methods:	Price-dependent, single-equation switching regressions with abrupt switch point
	Findings:	Structural change in beef and pork; new beef structure post-1971; new pork structure post-1969.
Chavas (1982)		Annual 1950–1979 / poultry, beef and pork
	Methods:	Quantity-dependent with random coefficients in demand system
	Findings:	Structural change in beef and poultry in post-1975 period.
Choi & Sosin (1990)		Annual 1953–1984 / red meat, poultry, other foods
	Methods:	Translog utility function with time-varying multiplicative terms; quantity-dependent translog demand function
	Findings:	Structural change occurred in the early 1970s.
Cornell & Sorenson(1986)		Annual 1950–1982 / beef, table beef, ground beef, pork, broilers
	Methods:	Price-dependent, discrete and continuous time varying parameters
	Findings:	Structural change for beef and poultry but not pork; post-1979.
Dahlgran (1986)		Annual 1950–1984 / beef, pork, chicken
	Methods:	Price-dependent system, gradually switching regression
	Findings:	Structural change in beef, pork and chicken; post-1973.
Frank (1984)		Quarterly 1970–1983 / beef, pork, chicken
	Methods:	Quantity-dependent system of equations; gradually switching regression
	Findings:	Structural change 1975(3) for beef, chicken, and pork.

Table A.1 (continued)

Haidacher et al.(1982)		Annual 1953–1977 / beef, veal, pork, chicken, turkey, and 37 others
	Methods:	Complete system of constant elasticity demand equations for some 40 food and 1 non-food categories: goodness of fit criterion
	Findings:	Goodness of fit to sample data with constant structure leaves less than 5% unexplained variation.
Jolly (1983)		Annual 1960–1980 / beef
	Methods:	Quantity-dependent, single-equation; R^2 goodness of fit
	Findings:	No structural change; virtually all sample variation explained with constant structure.
Leuthold & Nwagbo (1977)		Monthly, quarterly 1964–1975 / beef, pork, broilers
	Methods:	Quantity-dependent, single-equation with two 5-year subperiods; Chow test
	Findings:	No significant change in coefficients except for broilers using quarterly data.
Moschini & Meilke (1984)		Quarterly 1966–1981 / beef
	Methods:	Quantity-dependent, single-equation, Box-Cox tansformed demand functions
	Findings:	No evidence of structural change, although elasticities change.
Moschini & Meilke (1989)		Quarterly 1967–1987 / beef, pork, chicken, fish
	Methods:	Quantity dependent, single-equation spline model
	Findings:	Structural change for beef and chicken; not for pork.
Nyankori & Miller (1982)		Quarterly 1960–1979 / beef, pork, chicken, turkey
	Methods:	Quantity dependent, single-equation spline model
	Findings:	Structural change for beef and chicken; not for pork.

Table A.1 (contiuned)

Wohlgenant (1982,1986)	Annual 1947-1979 / beef, pork, poultry
Methods:	Rotterdam system for meat subgroup; standardizes for changes in nutritional components over time
Findings:	Structural change for beef, poultry; quality changes explain 1/2 of unexplained increase in poultry and 1/3 of decrease in beef.

Part of the table is cited from Smallwood _et al_.(1986).

Appendix B

This appendix gives a general proof of the symmetry condition for Hicksian demand.

The consumer's utility-maximization problem is set up as follows:

$$\text{Max } U(q_1, q_2) \tag{A.1}$$

$$\text{st. } p_1q_1 + p_2q_2 = M$$

and the Lagrange function is written as:

$$L = U(q_1, q_2) + \lambda\,(M - p_1q_1 - p_2q_2) \tag{A.2}$$

The first order conditions for this maximization problem are:

$$\partial L/\partial q_1 = U_1 - \lambda p_1 = 0 \tag{A.3}$$

$$\partial L/\partial q_2 = U_2 - \lambda p_2 = 0$$

$$\partial L/\partial \lambda = M - p_1q_1 - p_2q_2 = 0$$

where U_i is $\partial U/\partial q_i$.

Since the equation (A.3) must hold as an identity, they can be totally differentiated:

$$U_{11}\,dq_1 + U_{12}\,dq_2 - p_1\,d\lambda - \lambda\,dp_1 = 0 \tag{A.4}$$

$$U_{21}\,dq_1 + U_{22}\,dq_2 - p_2\,d\lambda - \lambda\,dp_2 = 0$$

$$-p_1\,dq_1 - p_2\,dq_2 - q_1\,dp_1 - q_2\,dp_2 + dM = 0$$

Rearranging with the endogenous variables on the left hand side and the exogenous variables on the right hand side:

$$U_{11}\,dq_1 + U_{12}\,dq_2 - p_1\,d\lambda = \lambda\,dp_1 \tag{A.4a}$$

$$U_{21}\,dq_1 + U_{22}\,dq_2 - p_2\,d\lambda = + \lambda\,dp_2$$

$$-p_1\,dq_1 - p_2\,dq_2 = q_1\,dp_1 + q_2\,dp_2 - dM$$

This can be expressed in matrix notation as:

$$\begin{bmatrix} U_{11} & U_{12} & -p_1 \\ U_{21} & U_{22} & -p_2 \\ -p_1 & -p_2 & 0 \end{bmatrix} \begin{bmatrix} dq_1 \\ dq_2 \\ d\lambda \end{bmatrix} = \begin{bmatrix} \lambda dp_1 \\ \lambda dp_2 \\ q_1 dp_1 + q_2 dp_2 - dM \end{bmatrix}$$

(A.5)

$$= \begin{bmatrix} \lambda \\ 0 \\ q_1 \end{bmatrix} dp_1 + \begin{bmatrix} 0 \\ \lambda \\ q_2 \end{bmatrix} dp_2 + \begin{bmatrix} 0 \\ 0 \\ -1 \end{bmatrix} dM$$

Specific marginal changes in quantities demand can be investigated using Cramer's rule applied to (A.5). First, note that the determinant of this three element matrix can be expressed as:

$$|H| = \begin{vmatrix} U_{11} & U_{12} & -p_1 \\ U_{21} & U_{22} & -p_2 \\ -p_1 & -p_2 & 0 \end{vmatrix} = p_1 p_2 U_{12} + p_1 p_2 U_{22} - p_1 p_2 U_{22} - p_2^2 U_{11}$$

(A.6)

Using Cramer's rule, the marginal change in the Marshallian demand for good 1 resulting from a change in the price of good 2 can be expressed:

$$\frac{dq_1}{dp_2}\bigg|_{dq_1 = dM = 0} = \frac{\begin{bmatrix} 0 & U_{12} & -p_1 \\ \lambda & U_{22} & -p_2 \\ q_2 & -p_2 & 0 \end{bmatrix}}{|H|} = \frac{p_1 p_2 \lambda - p_2 q_2 U_{12} + p_1 q_2 U_{22}}{|H|}$$

(A.7)

and the marginal change of quantity 1 with respect to income is:

$$\frac{dq_1}{dM}\bigg|_{dp_1=dp_2=0} = \frac{\begin{vmatrix} 0 & U_{12} & -p_1 \\ 0 & U_{22} & -p_2 \\ -1 & -p_2 & 0 \end{vmatrix}}{|H|} = \frac{p_2 U_{12} - p_1 U_{22}}{|H|}$$

The income effect can be expressed as:

$$q_2 \frac{dq_1}{dM}\bigg|_{dp_1=dp_2=0} = q_2 \frac{p_2 U_{12} - p_1 U_{22}}{|H|}$$

(A.8)

Summing (A.7) and (A.8),

$$\frac{dq_1}{dp_2}\bigg|_{dM=dp_1=0} + q_2 \frac{dq_1}{dM}\bigg|_{dp_1=dp_2=0}$$

$$= \frac{p_1 p_2 \lambda - p_2 q_2 U_{12} + p_1 q_2 U_{22} + p_2 q_2 U_{12} - p_1 q_2 U_{22}}{|H|} = \frac{p_1 p_2 \lambda}{|H|}$$

(A.9)

The same procedure can be gone through to evaluate the change in quantity 2 with respect to a change in the price of good 1 and income:

$$\frac{dq_2}{dp_1}\bigg|_{dM=dp_2=0} = \frac{\begin{vmatrix} U_{11} & \lambda & -p_1 \\ U_{21} & 0 & -p_2 \\ -p_1 & q_1 & 0 \end{vmatrix}}{|H|} = \frac{p_1 p_2 \lambda - p_1 q_1 U_{21} + p_2 q_1 U_{11}}{|H|}$$

(A.10)

$$\frac{dq_2}{dM}\Big|_{dp_1=dp_2=0} = \frac{\begin{bmatrix} U_{11} & 0 & -p_1 \\ U_{21} & 0 & -p_2 \\ -p_1 & -1 & 0 \end{bmatrix}}{|H|} = \frac{p_1 U_{21} - p_2 U_{11}}{|H|}$$

and the income effect becomes:

$$q_1 \frac{dq_2}{dM}\Big|_{dp_1=dp_2=0} = q_1 \frac{p_1 U_{21} - p_2 U_{11}}{|H|} \tag{A.11}$$

Again, summing (A.10) and (A.11):

$$\frac{dq_2}{dp_1}\Big|_{dM=dp_2=0} + q_1 \frac{dq_2}{dM}\Big|_{dp_1=dp_2=0}$$

$$= \frac{p_1 p_2 \lambda - p_1 q_1 U_{21} + p_2 q_1 U_{11} + p_1 q_1 U_{21} - p_2 q_1 U_{11}}{|H|} = \frac{p_1 p_2 \lambda}{|H|} \tag{A.12}$$

Now, remember that the Slutsky equation can be expressed as:

$$\frac{dq_i}{dp_j}\Big|_{dM=0} = \frac{dq_i^c}{dp_j}\Big|_{dU=0} - q_j \frac{dq_i}{dM}\Big|_{dp_j=0}$$

$$\frac{dq_i^c}{dp_j}\Big|_{dU=0} = \frac{dq_i}{dp_j}\Big|_{dM=0} + q_j \frac{dq_i}{dM}\Big|_{dp_j=0} \tag{A.13}$$

The left hand side is the Hicksian cross-partial. We now show that this must be symmetric. From (A.9) and (A.12), it is obvious that

$$\frac{dq_1}{dp_2}\Big|_{dM=dp_1=0} + q_2 \frac{dq_1}{dM}\Big|_{dp_1=dp_2=0} = \frac{dq_2}{dp_1}\Big|_{dM=dp_2=0} + q_1 \frac{dq_2}{dM}\Big|_{dp_1=dp_2=0}$$

which is in fact an equality between two Hicksian cross-partials, ie.

$$\frac{dq_1^c}{dp_2}\Big|_{dU=0} = \frac{dq_2^c}{dp_1}\Big|_{dU=0}$$

This is known as the symmetry condition.

Appendix C

This appendix shows the derivation of the elasticities for the AIDS model. Some notations are as follow:

$P_i = \ln p_i \qquad x = \ln(M/P) \qquad M = \Sigma p_i q_i$ (constant)

$\ln P = \Sigma w_i P_i \qquad w_i = p_i q_i / M$ (constant)

and the model is written as:

$$w_i = (\alpha_i + \gamma_i) + \Sigma_j(\beta_{ij} + \theta_{ij})P_j + (\beta_i + \theta_i)x + \Sigma_k(\alpha_{ik} + \gamma_{ik})D_k$$

replace some variables with the notation above:

$$p_i q_i/M = (\alpha_i + \gamma_i) + \Sigma_j(\beta_{ij} + \theta_{ij})\ln p_j + (\beta_i + \theta_i)\ln(M/P)$$
$$+ \Sigma_k(\alpha_{ik} + \gamma_{ik})D_k$$
$$= (\alpha_i + \gamma_i) + \Sigma_j(\beta_{ij} + \theta_{ij})\ln p_j + (\beta_i + \theta_i)\ln M$$
$$-(\beta_i + \theta_i)\ln P + \Sigma_k(\alpha_{ik} + \gamma_{ik})D_k$$

$$\ln P = \Sigma_i w_i P_i = \Sigma_i w_i \ln p_i$$

take the derivative of lnP with respect to p_i and p_j, respectively:

$$\partial \ln P/\partial p_i = w_i\ (1/p_i) = (p_i q_i/M)\ (1/p_i) = q_i/M$$

$$\partial \ln P/\partial p_j = w_j\ (1/p_j) = (p_j q_j/M)\ (1/p_j) = q_j/M$$

Marshallian elasticities can be derived as follow:

Price elasticities:

1. $\partial(p_i q_i/M)/\partial p_i = 1/M\ (q_i + p_i\ \partial q_i/\partial p_i) = q_i/M\ (1 + p_i/q_i\ \partial q_i/\partial p_i)$

$$= q_i/M\ (1 + \varepsilon_{ii})$$
$$= (\beta_{ii} + \theta_{ii})\ 1/p_i - (\beta_i + \theta_i)\ \partial P/\partial p_i\ 1/P$$

$$1 + \varepsilon_{ii} = (\beta_{ii} + \theta_{ii})\ M/p_i q_i - (\beta_i + \theta_i)\ \partial P/\partial p_i\ 1/P\ M/q_i$$

$$\varepsilon_{ii} = (\beta_{ii} + \theta_{ii})\ M/p_iq_i - (\beta_i + \theta_i)\ \partial lnP/\partial p_i\ M/q_i - 1$$

$$= (\beta_{ii} + \theta_{ii})\ M/p_iq_i - (\beta_i + \theta_i)\ q_i/M\ M/q_i - 1$$

$$= (\beta_{ii} + \theta_{ii})\ 1/w_i - (\beta_i + \theta_i) - 1$$

2. $\partial(p_iq_i/M)/\partial p_j = 1/M\ (p_i\ \partial q_i/\partial p_j) = q_i/p_j\ p_i/M\ (p_j/q_i\ \partial q_i/\partial p_j)$

$$= w_i/p_j\ \varepsilon_{ij}$$

$$= (\beta_{ij} + \theta_{ij})\ 1/p_j - (\beta_i + \theta_i)\ \partial P/\partial p_j\ 1/P$$

$$\varepsilon_{ij} = (\beta_{ij} + \theta_{ij})\ 1/p_j\ p_j/w_i - (\beta_i + \theta_i)\ \partial P/\partial p_j\ 1/P\ p_j/w_i$$

$$= (\beta_{ij} + \theta_{ij})\ 1/w_i - (\beta_i + \theta_i)\ \partial lnP/\partial p_j\ p_j/w_i$$

$$= (\beta_{ij} + \theta_{ij})\ 1/w_i - (\beta_i + \theta_i)\ q_j/M\ p_j/w_i$$

$$= (\beta_{ij} + \theta_{ij})\ 1/w_i - (\beta_i + \theta_i)\ w_j/w_i$$

Income elasticity:

3. $\partial(p_iq_i/M)/\partial M = p_i(\partial q_i/\partial M\ 1/M - q_i/M^2)$

$$= p_iq_i/M\ (\partial q_i/\partial M\ M/q_i\ 1/M - q_i/M^2\ M/q_i)$$

$$= w_i\ (\eta_i\ 1/M - 1/M)$$

$$= w_i/M\ (\eta_i - 1)$$

$$= (\beta_i + \theta_i)\ 1/M$$

$$\eta_i - 1 = (\beta_i + \theta_i)/w_i$$

$$\eta_i = (\beta_i + \theta_i)/w_i + 1$$

Appendix D

This appendix reports the parameter estimates for some of the estimated models. Throughout this appendix, the standard errors are found in parenthesis below the parameters estimates.

The definition of variables for models A.II and A.III are:

LQB=log(quantity of beef),	LQP=log(quantity of pork),
LQC=log(quantity of chicken),	LQT=log(quantity of turkey),
LPB=log(price of beef),	LPP=log(price of pork),
LPC=log(price of chicken),	LPT=log(price of turkey),
LY=log(price of expenditure),	LQB=log(quantity of beef),
LQP=log(quantity of pork),	LQC=log(quantity of chicken),
LQT=log(quantity of turkey),	LCL=log(cholesterol),
LCLLPB=LCL*LPB,	LCLLPP=LCL*LPP,
LCLLPC=LCL*LPC,	LCLLPT=LCL*LPT,
LCLLY=LCL*LY,	LCLLDi=LCL*Di,
LCLLQP=LCL*LQP,	LCLLQB=LCL*LQB,
LCLLQC=LCL*LQC,	LCLLQT=LCL*LQT,

Di=seasonal dummy variables.

Models A.II and A.III which are versions of the log linear demand systems were not found to be statistically adequate.

Table D.1 The parameter estimates for model A.II.

Independent Variables	Dependent variables: Quantity of			
	Beef(LQB)	Pork(LQP)	Chicken(LQC)	Turkey(LQT)
CONST	0.421319	1.756441	-1.113003	2.523998
	(0.218497)	(0.211415)	(0.259646)	(0.960965)
LPB	-0.518570	0.527491	-0.111286	0.769941
	(0.092884)	(0.089873)	(0.110377)	(0.408510)
LPP	0.214333	-0.831638	0.180213	-0.414045
	(0.073064)	(0.070696)	(0.086824)	(0.321341)
LPC	-0.100941	0.009993	-0.258175	0.608966
	(0.061687)	(0.059688)	(0.073304)	(0.271304)
LPT	0.004231	-0.013749	-0.005991	-0.658532
	(0.029936)	(0.028966)	(0.035574)	(0.131662)
LY	0.500704	-0.013418	0.855292	-1.030246
	(0.294860)	(0.285302)	(0.350390)	(1.296810)
D1	0.068303	0.071360	-0.027174	-0.062235
	(0.025471)	(0.024645)	(0.030268)	(0.112023)
D2	0.084546	0.077620	-0.062892	0.124488
	(0.026311)	(0.025458)	(0.031266)	(0.115718)
D3	0.011117	0.142162	-0.120041	0.890295
	(0.020105)	(0.019454)	(0.023892)	(0.088425)
LPB_1	0.538595	-0.148026	-0.185502	-0.240861
	(0.104859)	(0.101460)	(0.124607)	(0.461177)
LPP_1	-0.183548	0.350799	0.097081	-0.623588
	(0.082917)	(0.080230)	(0.098533)	(0.364675)
LPC_1	-0.013163	-0.010316	0.221871	0.005918
	(0.066533)	(0.064377)	(0.079063)	(0.292617)
LPT_1	0.032631	0.028199	0.010260	0.200532
	(0.031679)	(0.030652)	(0.037645)	(0.139328)
LY_1	-0.504216	-0.032611	-0.652879	1.096307
	(0.294899)	(0.285340)	(0.350436)	(1.296982)
LQB_1	0.952351	0.099843	-0.116774	-0.311232
	(0.041244)	(0.039907)	(0.049011)	(0.181394)
LQP_1	-0.047471	0.323355	0.304455	-1.451567
	(0.088764)	(0.085887)	(0.105481)	(0.390391)
LQC_1	-0.058197	0.148443	0.710340	1.717325
	(0.070857)	(0.068560)	(0.084201)	(0.311634)
LQT_1	0.049685	0.090710	-0.108973	-0.125038
	(0.018745)	(0.018137)	(0.022275)	(0.082440)
R^2 :	0.915	0.919	0.986	0.957

Table D.2 The parameter estimates for model A.III.

Independent Variables	Dependent variables: Quantity of Beef(LQB)	Pork(LQP)	Chicken(LQC)	Turkey(LQT)
CONST	-0.470158	2.080322	-1.341460	-5.364964
	(0.487069)	(0.539162)	(0.565220)	(1.501365)
LPB	-0.767863	0.780720	-0.454586	-0.108226
	(0.220900)	(0.244526)	(0.256344)	(0.680913)
LPP	0.037989	-1.100330	0.392605	0.278071
	(0.170526)	(0.188764)	(0.197887)	(0.525638)
LPC	-0.112460	0.149942	-0.481379	-0.482918
	(0.148479)	(0.164359)	(0.172303)	(0.457679)
LPT	-0.004036	0.027485	-0.119409	-0.009809
	(0.046405)	(0.051368)	(0.053851)	(0.143040)
LY	0.361222	-0.237032	0.626461	1.011536
	(0.407123)	(0.450665)	(0.472447)	(1.254935)
D1	-0.108877	-0.044807	0.085476	0.423115
	(0.081192)	(0.089875)	(0.094219)	(0.250269)
D2	-0.028356	-0.046202	0.047300	1.077961
	(0.069818)	(0.077285)	(0.081020)	(0.215210)
D3	-0.040498	0.076166	-0.081326	1.848369
	(0.044837)	(0.049632)	(0.052031)	(0.138207)
LCLLPB	0.057313	-0.105837	0.154092	0.110191
	(0.061139)	(0.067678)	(0.070948)	(0.188457)
LCLLPP	0.023688	0.078856	-0.114349	-0.093771
	(0.044676)	(0.049454)	(0.051845)	(0.137712)
LCLLPC	0.017116	-0.032331	0.070422	0.207622
	(0.038723)	(0.042864)	(0.044936)	(0.119361)
LCLLPT	-0.003613	-0.017159	0.039829	-0.080408
	(0.013754)	(0.015224)	(0.015960)	(0.042395)
LCLLY	-0.007081	0.097431	-0.090896	-0.256902
	(0.084430)	(0.093460)	(0.097977)	(0.260251)
LCLS1	0.036293	0.012570	-0.023388	-0.066191
	(0.017834)	(0.019741)	(0.020695)	(0.054972)
LCLS2	0.022304	0.016724	-0.024565	-0.167338
	(0.016715)	(0.018503)	(0.019397)	(0.051523)
LCLS3	0.013018	0.006365	-0.007014	-0.200517
	(0.011908)	(0.013182)	(0.013819)	0.036707
LCL	-0.334949	-0.442377	0.176005	1.557053
	(0.602801)	(0.667271)	(0.699521)	(1.858101)
LPB_1	0.435344	-0.726831	0.209786	0.974703
	(0.276319)	(0.305872)	(0.320655)	(0.851739)
LPP_1	0.034112	0.466871	-0.065393	0.039710
	(0.157848)	(0.174730)	(0.183175)	(0.486557)
LPC_1	-0.103476	-0.016269	0.441891	-0.868607
	(0.144490)	(0.159943)	(0.167674)	(0.445382)

Table D.2 (continued)

Independent Variables	Dependent variables: Quantity of			
	Beef(LQB)	Pork(LQP)	Chicken(LQC)	Turkey(LQT)
LPT_1	0.022508	0.044617	0.017301	0.236881
	(0.039030)	(0.043205)	(0.045293)	(0.120309)
LY_1	0.302488	0.462478	−0.357228	−0.532019
	(0.436527)	(0.483214)	(0.506568)	(1.345571)
LQB_1	0.381175	−0.226475	0.152864	0.358419
	(0.209457)	(0.231859)	(0.243065)	(0.645642)
LQP_1	−0.134222	0.229521	0.111270	0.087169
	(0.200913)	(0.222401)	(0.233150)	(0.619304)
LQC_1	−0.294319	0.261494	0.363350	−0.553630
	(0.155769)	(0.172429)	(0.180762)	(0.480150)
LQT_1	−0.054150	0.029055	−0.040791	0.086130
	(0.051219)	(0.056697)	(0.059437)	(0.157879)
LCLLPB_1	−0.010908	0.148856	−0.106554	−0.305223
	(0.070571)	(0.078119)	(0.081895)	(0.217533)
LCLLPP_1	−0.056613	−0.030892	0.021966	−0.051983
	(0.045516)	(0.050384)	(0.052819)	(0.140300)
LCLLPC_1	0.012800	0.019669	−0.084364	0.155850
	(0.036400)	(0.040293)	(0.042241)	(0.112202)
LCLLPT_1	0.000881	−0.010402	−0.004606	−0.034713
	(0.015020)	(0.016626)	(0.017430)	(0.046299)
LCLLY_1	−0.097400	−0.145889	0.076621	0.232886
	(0.089091)	(0.098619)	(0.103385)	(0.274617)
LCLLQB_1	0.007990	0.041352	−0.103032	−0.221585
	(0.054158)	(0.059950)	(0.062848)	(0.166939)
LCLLQP_1	−0.026807	0.030922	−0.065218	−0.126923
	(0.054958)	(0.060836)	(0.063777)	(0.169407)
LCLLQC_1	0.031123	−0.029041	0.079684	0.334722
	(0.045561)	(0.050434)	(0.052871)	(0.140439)
LCLLQT_1	0.024261	−0.001134	−0.002201	−0.007573
	(0.011741)	(0.012996)	(0.013624)	(0.036190)
LCL_1	0.959933	0.436402	0.378469	−0.410242
	(0.612836)	(0.678380)	(0.711167)	(1.889035)
R^2 :	0.940	0.926	0.990	0.985

The definitions of variables in models B.II and B.III are:

LRB=log(normalized price of beef), LQB=log(quantity of beef),

LRP=log(normalized price of pork), LQP=log(quantity of pork),

LRC=log(normalized price of chicken), LQC=log(quantity of chicken),

LRT=log(normalized price of turkey), LQT=log(quantity of turkey),

LS=log(scale), LCL=log(cholesterol),

LCLLRB=LCL*LRB, LCLLRP=LCL*LRP,

LCLLRC=LCL*LRC, LCLLRT=LCL*LRT,

LCLLS=LCL*LS, LCLLDi=LCL*Di,

LCLLQP=LCL*LQP, LCLLQB=LCL*LQB,

LCLLQC=LCL*LQC, LCLLQT=LCL*LQT,

Di=seasonal dummy variables.

These inverse demand models were not found to be statistically adequate.

Table D.3 The parameter estimates for model B.II.

Independent Variables	Dependent variables: price of			
	Beef(LRB)	Pork(LRP)	Chicken(LRC)	Turkey(LRT)
CONST	-3.966812	-0.166682	5.503016	-12.495733
	(1.299573)	(1.830580)	(4.350666)	(8.817153)
LQB	-0.093839	-0.533859	-1.139171	1.922264
	(0.175695)	(0.247484)	(0.588184)	(1.192027)
LQP	0.276237	-0.900190	-0.751293	0.801850
	(0.098543)	(0.138807)	(0.329897)	(0.668577)
LQC	0.133981	-0.158209	-0.557128	0.058608
	(0.048535)	(0.068366)	(0.162484)	(0.329293)
LQT	0.018945	-0.034343	-0.034273	-0.203704
	(0.013801)	(0.019441)	(0.046204)	(0.093637)
LS	-1.112456	0.504893	1.092072	-4.424855
	(0.333078)	(0.469174)	(1.115067)	(2.259818)
D1	-0.002682	-0.022259	0.038286	0.098817
	(0.014199)	(0.020001)	(0.047536)	(0.096338)
D2	-0.016064	-0.002297	0.057979	0.143522
	(0.013876)	(0.019546)	(0.046454)	(0.094144)
D3	-0.028919	0.026975	-0.022591	0.437471
	(0.014457)	(0.020365)	(0.048400)	(0.098088)
LQB_1	-0.375974	0.268347	0.174212	-0.670945
	(0.250372)	(0.352674)	(0.838185)	(1.698684)
LQP_1	-0.450779	0.433165	0.534456	-0.198703
	(0.162549)	(0.228966)	(0.544174)	(1.102835)
LQC_1	-0.177922	0.120101	0.075528	0.782203
	(0.062613)	(0.088196)	(0.209613)	(0.424805)
LQT_1	-0.030630	0.031682	-0.003241	-0.018245
	(0.015690)	(0.022101)	(0.052527)	(0.106452)
LS_1	0.258695	-0.501541	1.119898	0.126969
	(0.410209)	(0.577821)	(1.373284)	(2.783127)
LRB_1	0.017820	-0.166207	0.237438	-0.915993
	(0.297243)	(0.418696)	(0.995099)	(2.016689)
LRP_1	-0.412714	0.549488	0.415910	-0.475205
	(0.173750)	(0.244744)	(0.581673)	(1.178831)
LRC_1	-0.204524	0.029214	0.708152	0.474148
	(0.061169)	(0.086162)	(0.204778)	(0.415007)
LRT_1	-0.022412	-0.022765	0.051229	0.318893
	(0.022473)	(0.031655)	(0.075233)	(0.152469)
R^2 :	0.973	0.965	0.962	0.870

Table D.4 The parameter estimates for model B.III.

Independent Variables	Dependent variables: price of			
	Beef(LRB)	Pork(LRP)	Chicken(LRC)	Turkey(LRT)
CONST	-0.009413	-7.265066	-2.993132	-2.019873
	(3.569147)	(4.938540)	(11.580708)	(21.823570)
LQB	-0.952615	0.273962	0.111933	5.114952
	(0.486157)	(0.672684)	(1.577420)	(2.972611)
LQP	-0.195931	-0.328282	-0.179596	2.272523
	(0.272872)	(0.377566)	(0.885380)	(1.668478)
LQC	0.025020	0.081541	-0.481158	0.024723
	(0.101170)	(0.139986)	(0.328263)	(0.618603)
LQT	-0.055291	0.036746	-0.026570	0.222465
	(0.041506)	(0.057431)	(0.134674)	(0.253790)
LS	0.298763	-1.069438	-0.253290	-9.855991
	(0.857084)	(1.185925)	(2.780954)	(5.240642)
D1	0.022719	0.005266	-0.092420	-0.201458
	(0.047518)	(0.065750)	(0.154181)	(0.290551)
D2	0.049737	-0.019777	-0.041429	-0.381733
	(0.047572)	(0.065824)	(0.154355)	(0.290878)
D3	0.044249	-0.021460	-0.066930	-0.025150
	(0.054035)	(0.074767)	(0.175327)	(0.330399)
LCLLQB	0.145982	-0.193308	-0.189045	-0.879699
	(0.118455)	(0.163904)	(0.384349)	(0.724296)
LCLLQP	0.091719	-0.151704	-0.057671	-0.469315
	(0.070239)	(0.097188)	(0.227902)	(0.429476)
LCLLQC	0.010845	-0.073238	-0.032850	0.097477
	(0.036212)	(0.050106)	(0.117496)	(0.221418)
LCLLQT	0.010762	-0.016006	0.013723	-0.076221
	(0.009419)	(0.013033)	(0.030561)	(0.057591)
LCLLS	-0.237752	0.395761	0.063966	1.612723
	(0.221943)	(0.307097)	(0.720131)	(1.357071)
LCLS1	-0.000510	-0.020608	0.028736	0.106198
	(0.011194)	(0.015489)	(0.036321)	(0.068446)
LCLS2	-0.010236	-0.012390	0.018475	0.167656
	(0.011353)	(0.015709)	(0.036838)	(0.069420)
LCLS3	-0.011666	-0.001526	-0.004311	0.123727
	(0.013161)	(0.018210)	(0.042703)	(0.080472)
LCL	-0.672978	1.090542	0.778116	3.429549
	(0.567334)	(0.785006)	(1.840813)	(3.468969)
LQB_1	-0.105203	0.489992	0.817051	-10.945911
	(0.551383)	(0.762935)	(1.789056)	(3.371434)
LQP_1	-0.120761	0.254198	0.416717	-4.999913
	(0.359718)	(0.497733)	(1.167168)	(2.199500)
LQC_1	-0.133408	0.155444	-0.167939	0.208814
	(0.109604)	(0.151657)	(0.355630)	(0.670175)

Table D.4 (contiuned)

Independent Variables	Dependent variables: price of			
	Beef(LRB)	Pork(LRP)	Chicken(LRC)	Turkey(LRT)
LQT_1	-0.007757	0.085798	-0.051535	-0.801019
	(0.040119)	(0.055512)	(0.130174)	(0.245309)
LS_1	0.299018	-1.519049	-0.621325	11.365380
	(1.071368)	(1.482425)	(3.476236)	(6.550885)
LRB_1	0.260082	-0.483832	0.213581	-5.040538
	(0.499596)	(0.691278)	(1.621023)	(3.054780)
LRP_1	-0.211781	0.160306	0.355488	-1.998681
	(0.316600)	(0.438072)	(1.027263)	(1.935853)
LRC_1	-0.170102	0.001764	0.284677	0.878514
	(0.120023)	(0.166073)	(0.389436)	(0.733884)
LRT_1	0.011005	-0.026204	-0.039240	-0.040946
	(0.035468)	(0.049077)	(0.115083)	(0.216872)
LCLLQB_1	-0.204557	0.031621	0.551890	2.322648
	(0.159741)	(0.221030)	(0.518307)	(0.976738)
LCLLQP_1	-0.167187	0.092087	0.359050	1.251682
	(0.106216)	(0.146969)	(0.344637)	(0.649461)
LCLLQC_1	-0.034772	0.033288	0.228224	-0.091443
	(0.046608)	(0.064490)	(0.151228)	(0.284985)
LCLLQT_1	-0.007042	-0.024157	0.047556	0.223392
	(0.009812)	(0.013577)	(0.031837)	(0.059996)
LCLLS_1	-0.039333	0.358416	0.053886	-2.780130
	(0.286918)	(0.397001)	(0.930953)	(1.754360)
LCLLRB_1	-0.217239	0.251247	0.474426	0.706941
	(0.176716)	(0.244518)	(0.573386)	(1.080533)
LCLLRP_1	-0.138099	0.168956	0.260885	0.347257
	(0.106483)	(0.147338)	(0.345502)	(0.651091)
LCLLRC_1	-0.041535	0.047714	0.182505	-0.176291
	(0.044829)	(0.062029)	(0.145456)	(0.274109)
LCLLRT_1	-0.017055	0.003054	0.056014	0.112861
	(0.012628)	(0.017473)	(0.040974)	(0.077215)
LCL_1	-0.414409	1.310383	0.597917	-6.244833
	(0.939412)	(1.299842)	(3.048084)	(5.744042)
R^2 :	0.972	0.965	0.963	0.891

The definitions of the variables in models C.I and C.II are:

P1-log(price of beef), P2-log(price of pork),

P3-log(price of chicken), P4-log(price of turkey),

X-log(expenditure of four meats/stone price index),

W1-share of beef, W2-share of pork,

W3-share of chicken, Di-seasonal dummies,

LCL-log(the cholesterol variable), LCLPi-LCL*Pi,

LCLWi-LCL*Wi, LCLX-LCL*X,

LCLDi-LCL*Di, D(variable)-the first difference of the variable.

Model C.I, the original first difference model, and Model C.II, a general dynamic version of AIDS model with log of the cholesterol variable to model the structural change, were not found to be statistically adequate.

Table D.5 The parameter estimates for model C.I.

Independent Variables	Dependent variables: share of		
	Beef(DW1)	Pork(DW2)	Chicken(DW3)
CONST	-0.000394	-0.000034	0.000512
	(0.000923)	(0.000829)	(0.000357)
DP1	0.038148	0.089017	-0.080559
	(0.058899)	(0.052945)	(0.022794)
DP2	-0.041210	0.012676	0.009951
	(0.043023)	(0.038674)	(0.016650)
DP3	-0.019695	-0.022517	0.057196
	(0.037305)	(0.033534)	(0.014437)
DP4	-0.015612	0.007521	-0.010345
	(0.010157)	(0.009130)	(0.003931)
DX	-0.104104	0.108860	-0.051758
	(0.073414)	(0.065993)	(0.028411)
DD1	0.025567	0.011866	-0.000039
	(0.007112)	(0.006393)	(0.002752)
DD2	0.031605	-0.015822	0.017853
	(0.007774)	(0.006988)	(0.003008)
DD3	0.033116	-0.024773	0.016148
	(0.005716)	(0.005138)	(0.002212)
DLCLP1	0.003046	-0.021096	0.007041
	(0.015712)	(0.014124)	(0.006081)
DLCLP2	0.008527	0.004521	-0.008202
	(0.012061)	(0.010842)	(0.004668)
DLCLP3	-0.010584	-0.000673	0.009261
	(0.010402)	(0.009350)	(0.004025)
DLCLP4	0.001729	-0.005114	0.001491
	(0.003809)	(0.003424)	(0.001474)
DLCLX	0.041735	-0.030649	0.001084
	(0.020140)	(0.018104)	(0.007794)
DLCLD1	0.000676	-0.004433	0.000946
	(0.001898)	(0.001706)	(0.000735)
DLCLD2	-0.000125	-0.000779	-0.001544
	(0.001956)	(0.001758)	(0.000757)
DLCLD3	-0.000397	0.000703	-0.001758
	(0.001411)	(0.001268)	(0.000546)
DLCL	-0.170370	0.212800	-0.040839
	(0.097115)	(0.087298)	(0.037583)
R^2 :	0.872	0.831	0.933

Table D.6 The parameter estimates for model C.II.

Independent Variables	Dependent variables: share of Beef(W1)	Pork(W2)	Chicken(W3)
CONST	-0.334588	1.263209	-0.090471
	(0.550607)	(0.471956)	(0.213006)
P1	0.002708	0.130121	-0.092585
	(0.064615)	(0.055385)	(0.024997)
P2	0.011167	-0.073275	0.042314
	(0.051333)	(0.044000)	(0.019858)
P3	-0.030412	-0.009782	0.046508
	(0.046934)	(0.040230)	(0.018157)
P4	-0.014555	0.011626	-0.015079
	(0.014002)	(0.012002)	(0.005417)
X	-0.091880	0.088937	-0.004011
	(0.082697)	(0.070884)	(0.031992)
D1	0.025013	0.008978	0.009198
	(0.015465)	(0.013256)	(0.005983)
D2	0.026291	-0.016844	0.026564
	(0.014465)	(0.012398)	(0.005596)
D3	0.035501	-0.024711	0.016983
	(0.009473)	(0.008120)	(0.003665)
LCLP1	0.013465	-0.034297	0.011617
	(0.018034)	(0.015458)	(0.006977)
LCLP2	0.006633	0.018128	-0.019176
	(0.014332)	(0.012285)	(0.005544)
LCLP3	-0.013212	-0.000703	0.012882
	(0.012141)	(0.010407)	(0.004697)
LCLP4	0.002472	-0.007181	0.003585
	(0.004285)	(0.003673)	(0.001658)
LCLX	0.051384	-0.033651	-0.014789
	(0.023514)	(0.020155)	(0.009096)
LCLD1	-0.001243	-0.005495	0.002444
	(0.004288)	(0.003676)	(0.001659)
LCLD2	0.003196	-0.002641	-0.003349
	(0.003121)	(0.002675)	(0.001208)
LCLD3	0.001085	-0.000065	-0.003011
	(0.002354)	(0.002018)	(0.000911)
LCL	-0.251587	0.240645	0.028240
	(0.111245)	(0.095354)	(0.043036)
W1_1	0.674784	-0.601296	0.025499
	(0.547673)	(0.469442)	(0.211871)
W2_1	0.205498	-0.217373	0.100075
	(0.597688)	(0.512313)	(0.231220)
W3_1	-0.470500	0.081565	0.423978
	(0.639104)	(0.547813)	(0.247242)

Table D.6 (contiuned)

Independent Variables	Dependent variables: share of		
	Beef(W1)	Pork(W2)	Chicken(W3)
P1_1	0.065599	-0.113999	0.028603
	(0.070991)	(0.060850)	(0.027463)
P2_1	-0.011987	0.055897	-0.025953
	(0.049007)	(0.042007)	(0.018959)
P3_1	0.019122	-0.039405	0.023481
	(0.052336)	(0.044860)	(0.020247)
P4_1	0.013765	-0.014017	-0.000471
	(0.017055)	(0.014619)	(0.006598)
X_1	0.150582	-0.182365	0.031800
	(0.081153)	(0.069561)	(0.031394)
LCLP1_1	-0.023784	0.029903	0.000614
	(0.017829)	(0.015282)	(0.006897)
LCLP2_1	-0.008833	-0.011656	0.015163
	(0.014263)	(0.012226)	(0.005518)
LCLP3_1	0.023621	0.007587	-0.029281
	(0.016137)	(0.013832)	(0.006243)
LCLP4_1	-0.008425	0.004849	0.003280
	(0.004914)	(0.004212)	(0.001901)
LCLX_1	-0.049234	0.045922	0.000991
	(0.021922)	(0.018790)	(0.008481)
LCLW1_1	-0.298675	0.176357	0.088088
	(0.145631)	(0.124828)	(0.056338)
LCLW2_1	-0.310019	0.203652	0.063398
	(0.156063)	(0.133771)	(0.060374)
LCLW3_1	-0.368241	0.081501	0.227544
	(0.205938)	(0.176521)	(0.079668)
LCL_1	0.581102	-0.478890	-0.068882
	(0.182911)	(0.156784)	(0.070761)
R^2 :	0.919	0.900	0.964

The D.II models are the general dynamic versions of the AIDS models. Tables D.7, D.8, D.9 and D.10 present the estimation results for D.II(spline), D.II(fh), D.II(chol) and D.II(lchol), respectively. Models use the data set that includes fish quantities and prices instead of turkey. These prices are all normalized (each price is deflated by the fish price) instead of nominal prices which were used in previous case (model C.II). The notation for these models is similar to model C.II except:

P1=log(normalized price of beef), P2=log(normalized price of pork), P3=log(normalized price of chicken),
H=spline path, HPi=H*Pi, HWi=H*Wi, HX=H*X, HDi=H*Di
FH=Farley-Hinich path, FHPi=FH*Pi, FHX=FH*X, FHWi=FH*Wi, FHDi=FH*Di, CL=the variable of cholesterol, CLPi=CL*Pi, CLWi=CL*Wi, CLDi=CL*Di, CLX=CL*X.

These models were found to be statistically adequate.

Table D.7 The parameter estimates for model D.II(spline).

Independent Variables	Dependent variables: share of		
	Beef(W1)	Pork(W2)	Chicken(W3)
CONST	0.032358	0.296813	0.045974
	(0.334224)	(0.312888)	(0.239615)
P1	0.040639	0.064237	-0.041984
	(0.033189)	(0.031070)	(0.023794)
P2	0.103827	-0.085856	-0.019993
	(0.038790)	(0.036314)	(0.027810)
P3	-0.072135	-0.013754	0.085304
	(0.027907)	(0.026126)	(0.020008)
X	0.195533	-0.111486	-0.061857
	(0.091651)	(0.085800)	(0.065707)
D1	0.010435	-0.021838	0.009121
	(0.005999)	(0.005616)	(0.004301)
D2	0.014844	-0.036222	0.016371
	(0.005882)	(0.005507)	(0.004217)
D3	0.015311	-0.023042	0.006363
	(0.003390)	(0.003173)	(0.002430)
HP1	0.064651	-0.084894	0.007756
	(0.041846)	(0.039174)	(0.030000)
HP2	-0.095712	0.054120	0.053757
	(0.051742)	(0.048439)	(0.037096)
HP3	0.066055	0.017455	-0.077032
	(0.029835)	(0.027930)	(0.021390)
HX	-0.058159	0.044781	0.035601
	(0.109213)	(0.102242)	(0.078298)
HD1	-0.003343	0.002351	0.003792
	(0.007888)	(0.007385)	(0.005655)
HD2	-0.007356	0.009728	0.000374
	(0.006908)	(0.006467)	(0.004953)
HD3	-0.002164	0.003374	0.001143
	(0.004229)	(0.003959)	(0.003032)
H	0.016615	-0.022630	-0.001079
	(0.019903)	(0.018632)	(0.014269)
W1_1	0.779479	-0.102911	-0.015146
	(0.336256)	(0.314791)	(0.241072)
W2_1	0.361418	0.326083	-0.097604
	(0.366160)	(0.342785)	(0.262511)
W3_1	-0.251882	-0.371460	0.781329
	(0.742360)	(0.694970)	(0.532220)
P1_1	-0.058607	-0.020836	0.036024
	(0.037250)	(0.034872)	(0.026705)
P2_1	-0.113688	0.065508	0.016738
	(0.030693)	(0.028733)	(0.022004)

Table D.7 (contiuned)

Independent Variables	Dependent variables: share of		
	Beef(W1)	Pork(W2)	Chicken(W3)
P3_1	0.066247	0.028004	-0.066006
	(0.038489)	(0.036032)	(0.027594)
X_1	-0.158907	-0.028509	0.050022
	(0.081784)	(0.076563)	(0.058633)
HP1_1	0.025642	-0.033806	0.002963
	(0.054830)	(0.051330)	(0.039309)
HP2_1	0.081226	-0.020634	-0.050774
	(0.039392)	(0.036877)	(0.028241)
HP3_1	-0.048084	-0.029258	0.049604
	(0.039703)	(0.037169)	(0.028464)
HX_1	0.018350	-0.052545	0.055094
	(0.111798)	(0.104661)	(0.080151)
HW1_1	-0.766155	0.822284	0.051426
	(0.429439)	(0.402024)	(0.307877)
HW2_1	-0.597153	0.529089	0.169490
	(0.450296)	(0.421550)	(0.322830)
HW3_1	-0.585876	0.812752	0.221287
	(0.815657)	(0.763587)	(0.584768)
H_1	0.594871	-0.627163	-0.092872
	(0.397264)	(0.371903)	(0.284810)
R^2 :	0.915	0.916	0.894

Table D.8 The parameter estimates for model D.II(fh).

Independent Variables	Dependent variables: share of		
	Beef(W1)	Pork(W2)	Chicken(W3)
CONST	0.052508	0.460283	0.105061
	(0.446907)	(0.411307)	(0.257038)
P1	0.076193	0.050005	-0.043299
	(0.051520)	(0.047416)	(0.029632)
P2	0.130778	-0.100855	-0.053715
	(0.057517)	(0.052935)	(0.033081)
P3	-0.118776	0.007416	0.104392
	(0.035438)	(0.032615)	(0.020382)
X	0.227311	-0.094257	-0.154390
	(0.123237)	(0.113420)	(0.070880)
D1	0.011634	-0.015803	0.002482
	(0.009099)	(0.008375)	(0.005234)
D2	0.012636	-0.029748	0.011986
	(0.007475)	(0.006880)	(0.004299)
D3	0.013168	-0.020679	0.006777
	(0.005343)	(0.004917)	(0.003073)
FHP1	0.012373	-0.103362	0.023962
	(0.096605)	(0.088909)	(0.055562)
FHP2	-0.171008	0.139494	0.104825
	(0.107626)	(0.099053)	(0.061901)
FHP3	0.137700	-0.024753	-0.102543
	(0.049611)	(0.045659)	(0.028534)
FHX	-0.189829	0.063791	0.232920
	(0.210903)	(0.194103)	(0.121301)
FHD1	-0.003074	-0.001216	0.008476
	(0.015938)	(0.014669)	(0.009167)
FHD2	-0.003946	0.005781	0.002839
	(0.012441)	(0.011450)	(0.007156)
FHD3	0.002349	-0.004456	0.002289
	(0.009322)	(0.008579)	(0.005361)
FH	0.865439	-1.151736	-0.220536
	(0.797284)	(0.733774)	(0.458557)
W1_1	0.882609	-0.322429	-0.118742
	(0.483618)	(0.445094)	(0.278153)
W2_1	0.258816	0.108915	-0.079981
	(0.490278)	(0.451224)	(0.281983)
W3_1	-0.745433	0.012893	0.545327
	(0.811772)	(0.747108)	(0.466890)
P1_1	-0.114126	-0.031439	0.098571
	(0.065588)	(0.060364)	(0.037723)
P2_1	-0.148596	0.104403	0.026074
	(0.052456)	(0.048277)	(0.030170)

Table D.8 (contiuned)

Independent Variables	Dependent variables: share of		
	Beef(W1)	Pork(W2)	Chicken(W3)
P3_1	0.126950	-0.013652	-0.075187
	(0.051094)	(0.047024)	(0.029387)
X_1	-0.222192	0.055233	0.032169
	(0.105735)	(0.097313)	(0.060814)
FHP1_1	0.136923	0.027487	-0.133441
	(0.126758)	(0.116661)	(0.072905)
FHP2_1	0.172610	-0.141130	-0.062348
	(0.098740)	(0.090875)	(0.056790)
FHP3_1	-0.142630	-0.006811	0.097601
	(0.064359)	(0.059232)	(0.037016)
FHX_1	0.072861	-0.137650	0.086287
	(0.177789)	(0.163627)	(0.102255)
FHW1_1	-1.208034	1.333611	0.304837
	(0.946410)	(0.871021)	(0.544327)
FHW2_1	-0.890600	1.118404	0.338244
	(0.823963)	(0.758328)	(0.473902)
FHW3_1	-0.181080	1.242713	0.073850
	(1.253186)	(1.153360)	(0.720769)
R^2 :	0.911	0.915	0.928

Table D.9 The parameter estimates for model D.II(chol).

Independent Variables	Dependent variables: share of		
	Beef(W1)	Pork(W2)	Chicken(W3)
CONST	0.201039	0.064781	0.084831
	(0.233624)	(0.233922)	(0.147867)
P1	0.076914	0.036340	-0.051140
	(0.028623)	(0.028660)	(0.018116)
P2	0.106235	-0.043054	-0.059929
	(0.034524)	(0.034568)	(0.021851)
P3	-0.101160	0.007420	0.090410
	(0.022981)	(0.023010)	(0.014545)
X	0.164015	0.018940	-0.156455
	(0.068247)	(0.068334)	(0.043196)
D1	0.010820	-0.023936	0.010678
	(0.005632)	(0.005639)	(0.003564)
D2	0.010514	-0.030910	0.015945
	(0.004519)	(0.004525)	(0.002860)
D3	0.013009	-0.021591	0.008022
	(0.003175)	(0.003179)	(0.002010)
CLP1	0.000002	-0.000401	0.000149
	(0.000458)	(0.000459)	(0.000290)
CLP2	-0.000995	0.000228	0.001011
	(0.000501)	(0.000502)	(0.000317)
CLP3	0.000767	-0.000101	-0.000611
	(0.000218)	(0.000219)	(0.000138)
CLX	-0.000984	-0.000673	0.001944
	(0.000876)	(0.000877)	(0.000554)
CLD1	-0.000053	0.000088	-0.000019
	(0.000076)	(0.000076)	(0.000048)
CLD2	-0.000023	0.000057	-0.000013
	(0.000055)	(0.000055)	(0.000035)
CLD3	0.000020	-0.000006	-0.000015
	(0.000041)	(0.000041)	(0.000026)
CL	0.000591	-0.000509	-0.000048
	(0.000290)	(0.000291)	(0.000184)
W1_1	0.681583	0.064186	-0.063177
	(0.255902)	(0.256229)	(0.161967)
W2_1	0.115899	0.682089	-0.175440
	(0.260341)	(0.260673)	(0.164777)
W3_1	-0.741041	0.077926	0.865643
	(0.512233)	(0.512887)	(0.324206)
P1_1	-0.077834	-0.039552	0.069987
	(0.039744)	(0.039795)	(0.025155)
P2_1	-0.113417	0.031760	0.047473
	(0.031372)	(0.031412)	(0.019856)

Table D.9 (contiuned)

Independent Variables	Dependent variables: share of		
	Beef(W1)	Pork(W2)	Chicken(W3)
P3_1	0.097741	0.019623	-0.086663
	(0.035578)	(0.035623)	(0.022518)
X_1	-0.189908	0.011767	0.050926
	(0.064394)	(0.064477)	(0.040757)
CLP1_1	0.000661	0.000244	-0.000628
	(0.000662)	(0.000663)	(0.000419)
CLP2_1	0.000856	-0.000030	-0.000879
	(0.000507)	(0.000507)	(0.000321)
CLP3_1	-0.000755	-0.000235	0.000732
	(0.000323)	(0.000324)	(0.000205)
CLX_1	0.000272	-0.000592	0.000553
	(0.000747)	(0.000748)	(0.000473)
CLW1_1	-0.005246	0.005381	0.000292
	(0.004038)	(0.004043)	(0.002556)
CLW2_1	-0.002675	0.000314	0.003344
	(0.003629)	(0.003634)	(0.002297)
CLW3_1	-0.000512	0.005954	-0.002148
	(0.005575)	(0.005582)	(0.003528)
CL_1	0.002786	-0.002951	-0.000727
	(0.003398)	(0.003403)	(0.002151)
R^2 :	0.922	0.912	0.924

Table D.10 The parameter estimates for model D.II(lchol).

Independent Variables	Dependent variables: share of		
	Beef(W1)	Pork(W2)	Chicken(W3)
CONST	-0.012859	0.773372	0.077867
	(0.810951)	(0.739748)	(0.531589)
P1	0.089634	0.114908	-0.099189
	(0.078697)	(0.071787)	(0.051587)
P2	0.242125	-0.110129	-0.137602
	(0.103782)	(0.094669)	(0.068030)
P3	-0.187945	-0.032859	0.195310
	(0.062197)	(0.056736)	(0.040771)
X	0.376649	-0.212364	-0.227037
	(0.212797)	(0.194113)	(0.139491)
D1	0.005645	-0.018813	0.005297
	(0.012687)	(0.011573)	(0.008316)
D2	0.007508	-0.032136	0.015012
	(0.011210)	(0.010225)	(0.007348)
D3	0.005458	-0.014938	0.008391
	(0.008298)	(0.007569)	(0.005439)
LCLP1	-0.003280	-0.028401	0.016432
	(0.020997)	(0.019153)	(0.013764)
LCLP2	-0.049851	0.021541	0.034237
	(0.026427)	(0.024107)	(0.017323)
LCLP3	0.036484	0.006686	-0.036708
	(0.013922)	(0.012699)	(0.009126)
LCLX	-0.058534	0.041715	0.044408
	(0.052125)	(0.047548)	(0.034169)
LCLD1	0.001188	-0.000056	0.000831
	(0.003257)	(0.002971)	(0.002135)
LCLD2	0.000990	0.001082	-0.000318
	(0.002782)	(0.002538)	(0.001824)
LCLD3	0.002177	-0.001824	-0.000109
	(0.002083)	(0.001900)	(0.001365)
LCL	0.003010	-0.019599	0.011391
	(0.008778)	(0.008007)	(0.005754)
W1_1	1.041517	-0.774266	-0.100971
	(0.893342)	(0.814905)	(0.585598)
W2_1	0.444838	-0.124896	-0.176740
	(0.916081)	(0.835648)	(0.600504)
W3_1	-1.141226	-0.380801	0.890498
	(1.417945)	(1.293447)	(0.929482)
P1_1	-0.129863	-0.014661	0.115260
	(0.120571)	(0.109985)	(0.079036)
P2_1	-0.260560	0.091057	0.118393
	(0.095307)	(0.086939)	(0.062475)

Table D.10 (contiuned)

Independent Variables	Dependent variables: share of		
	Beef(W1)	Pork(W2)	Chicken(W3)
P3_1	0.158192	0.046009	-0.142820
	(0.090264)	(0.082339)	(0.059169)
X_1	-0.426676	0.284622	0.050724
	(0.172354)	(0.157221)	(0.112980)
LCLP1_1	0.025000	-0.002398	-0.023548
	(0.031343)	(0.028591)	(0.020546)
LCLP2_1	0.050781	-0.017451	-0.029441
	(0.024602)	(0.022442)	(0.016127)
LCLP3_1	-0.030071	-0.011147	0.028594
	(0.019424)	(0.017719)	(0.012733)
LCLX_1	0.060818	-0.074961	0.008406
	(0.042873)	(0.039108)	(0.028104)
LCLW1_1	-0.180557	0.320369	0.012248
	(0.236217)	(0.215477)	(0.154843)
LCLW2_1	-0.144173	0.244727	0.040328
	(0.225430)	(0.205637)	(0.147772)
LCLW3_1	0.107227	0.251871	-0.068771
	(0.338727)	(0.308986)	(0.222040)
LCL_1	0.111812	-0.239643	-0.015243
	(0.205634)	(0.187579)	(0.134796)
R^2 :	0.905	0.911	0.901

Vita

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In 1989, she received a scholarship and headed across the ocean to study at the Virginia Polytechnic Institute and State University, U.S.A., to pursue a Masters degree in Agricultural Economics. She received her Masters in 1991 and went back to Taiwan to provide the knowledge to her country.