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Quarterly fluctuations in meat demand functions

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QUARTERLY FLUCTUATIONS IN

MEAT DEMAND FUNCTIONS

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CHAPTER I. INTRODUCTION

Seasonal variation in demand has important economic implications for producers, retailers and consumers in the "market place" where the retailers bring the demand of consumers into contact with the supply of producers by means of inventory change and price adjustments. All three of these agents are affected by the parameters of the demand curve facing them. In the meat market knowledge of demand fluctuations is particularly important due to the perishability properties of the product. Tolley (44) explains that meat is generally transferred from slaughter house coolers rapidly to avoid continued shrinkage and ageing. These properties of meat impose important restrictions on the retailer in his use of inventory change as a means of intervening between fluctuating demand and supply.

Numerous studies of the demand for meats have been made using yearly data, e.g., Fox (10), Nordin (32), Stone (40) and Wold (69). However, analyses utilizing annual data are restricted to averages of the years ups and downs and may not reflect actual price conditions for any particular period of time within the year. Some commodities for which there is evidence of seasonal or thermal variations in demand are set out by Ladd (27, p. 151). Previous studies of the demand for meats using quarterly data include Fuller (13); Ladd and Martin (29); Logan and Boles (30) and Riley (35).

This analysis is concerned with the retail demand for beef, pork, broilers and mutton and lamb, with major emphasis on analyzing seasonal variation in the demand functions of these meats by means of quarterly data. The objectives of the study outlined in section 1.2 below is followed by the relevant economic and statistical considerations in Chapter II and III respectively. The procedure of analysis follows in Chapter IV which precede the final two chapters devoted to the discussion of results and Summary and Conclusions respectively.

The purpose of this study is two-fold (a) to investigate the nature of the quarterly fluctuations in the aggregate consumer demand functions of beef, pork, broilers and mutton and lamb and (b) to examine selected structural demand functions for each meat based on the results of purpose (a).

Part (a) is achieved operationally by testing two hypotheses. The first hypothesis is that the slopes of the demand functions for selected meats are constant by seasons within the year. The second hypothesis is that the level (i.e., intercept) of the demand function is constant among seasons of the year. Part (b) includes calculation of direct and cross price elasticities and flexibilities and income elasticities of demand for the four meats.

CHAPTER II. ECONOMIC THEORETICAL CONSIDERATIONS

2.1. Introduction

In this chapter theoretical aspects of economic phenomena relevant to this study are explained. Section 2.2 treats of the theory of consumer demand. The concept of elasticity is discussed in detail in section 2.3. Some theoretical aspects of empirical demand analysis is introduced in section 2.4 which concludes the chapter.

2.2. Theory of Consumer Demand

Modern micro-economic theory has developed slowly from its classical antecedents and in large measure owes its present form to the introduction of the subjective value theory into economics. This departure consists of a change from the notion of a good having intrinsic utility or want satisfying properties within itself to the more subjective idea that the utility derived is relative, and depends on all other commodities and on individual preferences.

By introducing the concept of substitutability between the different goods contributing to an unchanged total utility, Pareto[1] (34) paved the way for later economists to develop the modern theory of consumer behavior without resort to the assumption of cardinally measurable utility. These economists classify themselves as "ordinalists" because they say that all consumer behavior can be described in terms of preferences or rankings, in which the consumer need only state which of two collections of goods he prefers, without reporting on the magnitude of any numerical index of

[1] c. 1906.

the strength of this preference. This theory has been based on the "indifference map" of an individual which can be described by the following equation.

$$u = U(X_1, X_2, \ldots, X_n) \qquad [2.2.1]$$

Equation [2.2.1] is only one of many functions which can represent utility and any other function which orders consumption in the same way will serve. This means that U is determined only up to an increasing (monotonic) transformation. Using the utility function given by Equation [2.2.1] an indifference curve can be described by the equation

$$U(X_1, X_2, \ldots, X_n) = C \qquad [2.2.2]$$

where C is a constant. An indifference map is generated by allowing C to assume every possible value.

Let an indifference curve be represented by

$$U(X_1, X_2) = C$$

Taking the total derivative one obtains

$$\frac{\partial U}{\partial X_1} dX_1 + \frac{\partial U}{\partial X_2} dX_2 = 0$$

Solving for $\frac{dX_1}{dX_2}$, the slope of the indifference curve, it is found that

$$-\frac{dX_1}{dX_2} = \text{M.R.S. } X_1 \text{ for } X_2 = \frac{\partial U/\partial X_1}{\partial U/\partial X_2}$$

where M.R.S. is the marginal rate of substitution.

In indifference curve analysis it is customary to make these assumptions about the Psychology of the consumer

1. Non-Satiety: The consumer is not oversupplied with either commodity, i.e., he prefers to have more of X_i where $i = 1, 2, \ldots, n$.

2. Transitivity: If A, B, and D are any three commodity combinations and if A is indifferent with B and B is indifferent with D, then the consumer is also indifferent between A and D.

3. Diminishing marginal rate of substitution.

The economists responsible for developing the modern theory of consumer behavior from where Pareto finished were Slutsky (36), Hicks and Allen (20), Hotelling (22) and Hicks (18). By itself, an indifference map cannot predict consumer behavior because it leaves out two vital types of information - the income of the consumer and the prices of the commodities. The indifference curve fails to bring the quantities consumed down to a "common denominator" and to constrain those weighted quantities.

The principle assumption upon which the theory of consumer demand is built is that a consumer attempts to allocate his limited money income among available goods and services so as to maximize his satisfaction. Let the individual whose ordinal utility function is given by Equation [2.2.1] have money income M and have the possibility to purchase the n commodities on a market at given prices $P_1, P_2, \ldots, P_n$. The problem is to determine his demands $(X_1, X_2, \ldots, X_n)$ for maximum utility (U). The solution is that of restrained maximum found by the use of a simple Lagrangean multiplier as follows

Maximize U subject to $\sum_{i=1}^{n} P_i X_i = M$

$$\text{i.e., Max. } [U - \lambda(\sum_{i=1}^{n} P_i X_i - M)] = L \qquad [2.2.3]$$

Differentiating Equation [2.2.3] with respect to λ and X_i and equating the results to zero gives the first order conditions for a solution as: follows:

$$\frac{\partial L}{\partial \lambda} = \sum_{i=1}^{n} P_i X_i - M = 0 \rightarrow \sum_{i=1}^{n} P_i X_i = M \qquad [2.2.4]$$

$$\frac{\partial L}{\partial X_i} = \frac{\partial U}{\partial X_i} - \lambda P_i = 0 \rightarrow \frac{\partial U}{\partial X_i} = \lambda P_i \qquad [2.2.5]$$

From Equations [2.2.4] and [2.2.5] it can be seen that the marginal rate of substitution between any two goods must equal the ratio of their prices, i.e., $\frac{\partial U}{\partial X_i} \Big/ \frac{\partial U}{\partial X_j} = \frac{P_i}{P_j}$

The Equations [2.2.4] and [2.2.5] are the first order conditions for consumer equilibrium; they are sufficient in number to determine λ and the n demands $(X_1, X_2, \ldots, X_n)$ in terms of the given prices and income of the consumer as follows:

$$X_1 = F_i(P_1, P_2, \ldots, P_n, M) \qquad [2.2.6]$$

If the given money income (M) and prices (P_i) are regarded as parameters of such a "Demand Function" then a proportional increase in all the P's and in M leaves the Equations [2.2.4] and [2.2.5] unaffected except for a similar decrease in λ, i.e., consumer demand is not changed. Thus the demand functions are homogeneous of degree zero in the variables, i.e., only relative prices and income are involved. The second order conditions for a stable constrained maximum are given by the following for the two good (X_1 and X_2) case.

$$\frac{d^2U}{dX_1^2} = \frac{\partial^2 U}{\partial X_1^2} + 2\frac{\partial^2 U}{\partial X_1 \partial X_2}\left(-\frac{P_1}{P_2}\right) + \frac{\partial^2 U}{\partial X_2}\left(-\frac{P_1}{P_2}\right)^2 < 0$$

Multiplying by P_2^2, a positive number, one obtains

$$\frac{\partial^2 U}{\partial X_1^2} \; P_2 \; - 2 \frac{\partial^2 U}{\partial X_1 \partial X_2} P_1 P_2 \; + \; \frac{\partial^2 U}{\partial X_2^2} \; P_2^2 < 0 \qquad [2.2.7]$$

A true maximum is obtained if Equation [2.2.7] holds in addition to Equations [2.2.4] and [2.2.5] graphically. Equation [2.2.7] can be used to show that indifference curves must be concave from above to ensure a stable constrained maximum.

The first and second order conditions for a maximum can be further extended to give information on the nature of the total effect of a price change on the quantity demanded as shown by Ferguson (8 , p. 48). The decomposition of this total effect of a price change gives two effects known as (a) The Substitution Effect which is the change in quantity demanded attributable exclusively to a change in the price ratio and (b) The Income Effect which is the change in quantity demanded attributable exclusively to a change in real income.

2.3. Elasticity

The most obvious piece of information we desire of a demand function is an indication of the effect on the "dependent" variable (i.e., quantity demanded) of a change in the value of one of the other variables. When these other variables concerned are prices, one measure commonly used is called a "price elasticity" and when the other variable is income this is known as an "income elasticity". These are defined for the demand curve given by Equation [2.2.5] after Frisch as follows:

The price elasticities of demand are given by

$$e_{ik} = \frac{\partial f_i(p_1, p_2, \ldots, p_n, M)}{\partial p_k} \times \frac{p_k}{f_i(p_1, p_2, \ldots, p_n, M)} \qquad [2.3.1]$$

$i = 1, 2, \ldots, n; k = 1, 2, \ldots, n$

where e_{ik} are direct price elasticities of demand when $i = k$ and are cross-price elasticities of demand when $i \neq k$. The income elasticities of demand are given by

$$E_i = \frac{\partial f_i(p_1, p_2, \ldots, p_n, M)}{\partial M} \times \frac{M}{f_i(p_1, p_2, \ldots, p_n, M)} \qquad 2.3.2]$$

$i = 1, 2, \ldots, n$

where E_i are the income elasticities of demand. The direct price elasticity measures the percentage change in consumption of one commodity that is associated with a 1 percent change in the price of that commodity whereas the cross-price elasticity is the same percentage change in consumption due to a 1 percent change in price of a second commodity.

Elasticities have been used to describe substitutability and complementarity between commodities by Foote (9 , p. 81) as follows:

> "If the direct elasticity and cross elasticity have the same sign so that an increase in price of the second commodity results in a decrease in consumption of the first commodity, we say that they are complementary products. If the direct and cross elasticities are of opposite sign, so that an increase in price of the 2nd commodity results in an increase in consumption of the 1st commodity, we say that they are competing products. If the direct and cross elasticities are of the same magnitude when the respective quantities and prices are expressed in comparable terms, we say that the two commodities are perfect complements of substitutes. If the cross-elasticity equals zero, or nearly so, we assume that the two products are independent in demand".

Professor Watson (68, p. 40) is cited by Kuhlman and Thompson (26) in showing that both "elasticities" (i.e., direct and cross) refer to the same phenomenon. Kuhlman and Thompson go on to cite Hicks (18) in showing that the two elasticities are necessary in describing substitutability in the consumer basket whenever the "Income - effect" is significant.

Elasticity is a measure which is independent of the units in which the variables are measured being a ratio of percentage changes in the variables. The above definitions measure elasticity at a point and so it is called "Point Elasticity". The point to which this elasticity refers is determined by the coordinates given by the numerator and denominator of the second part of the elasticity "products" shown above. However, this measure becomes an "Average Elasticity" when the functions are expressed in logarithms. For the single good case this can be demonstrated as shown by Yamane (73, p. 70) as follows:

Let the demand curve be

$$q = f(p) \qquad [2.3.3]$$

then using the derivatives of logarithms,

$$\frac{d \ln q}{d p} = \frac{d \ln q}{d q} \cdot \frac{d q}{d p} = \frac{1}{q} = \frac{d q}{d p}$$

Also,

$$\frac{d \ln p}{d p} = \frac{1}{p}$$

Thus the elasticity of the demand curve is given by

$$e = \frac{\frac{d \ln q}{d q}}{\frac{d \ln p}{d p}} = \frac{d(\ln q)}{d(\ln p)} \qquad [2.3.4]$$

Thus in general demand functions of variables expressed in double logarithms have constant elasticity which is given by the first partial derivative with respect to the variable concerned.

Dynamic aspects are also relevant to the theory of consumer behavior. The inclusion of a time trend as an independent variable makes the demand function dynamic. Stigler (39, p. 95) gives some of the reasons for expecting the elasticity of demand to increase with time. The presence of technological rigidities, imperfections in the market, and habit are advanced to explain why the full effect of a price change may not be realized immediately. Wold (69, pp. 240-241) distinguishes between short and long term elasticities and says that in practical applications it is the long term elasticity that is of primary interest. He adds that elasticities based on data with trends included appear to be something intermediate between long and short term elasticities.

2.4. Some Empirical Aspects of Demand Analysis

Studies of market demand involve aggregation over individuals and commodities. The aggregation over individuals merely involves summation. The aggregation over commodities leads to elasticity measures which tend to be the average of the underlying commodity elasticities (Wold, 69). To take account of population and general price level changes studies are usually done on per capita data while prices are deflated by price indexes.

The raw material for demand analysis consists of points in k+1 dimensional space generated by the structural system underlying the dependent and k independent variables used in the analysis. However, estimation of this structure by fitting of a function to such data by the traditional single equation method frequently gives biased results due to the interdependence rather than the dependence between the variables. In this case the observed points represent price quantity combinations which are generated by the intersection of supply and demand curves, i.e., by simultaneous relationships.

Working (71, p. 114) mentioned that "ceteris paribus" is not a condition represented by a statistical law of demand or by any useful demand curve theory. Some of the things that are correlated with the price of the commodity in question may be held equal, but it is impossible for all things to be held equal. However, a statistical law of demand represents a condition under which the relationships between factors may be considered to have remained the same, or to put it more accurately a condition which is an average of the relationships during the period studied. Wold (69, p. 2) adds the following:

> "Demand functions as derived from empirical data should always be regarded as tentative, as more or less successful attempts to cover the complex realities behind the statistical observations by the simple pattern of a specified mathematical function."

CHAPTER III. THEORETICAL STATISTICAL CONSIDERATIONS

3.1. Introduction

One of the criteria for classifying a field of study as a science is the ability of that discipline to predict. One stage in the early development of most of the sciences was characterized by qualitativeness and lack of quantitative tools of description and analysis. In most cases development beyond this stage was accomplished through application of the mathematical sciences. The social sciences are particularly hampered by the inability to completely specify and control their pehnomena. Thus this area of science draws heavily on the science of Statistics. To allow for the above difficulty many relationships in economics are made statistical by including a term which serves as a "filter" mechanism to take account of variables excluded from the model and also to serve as a stochastic disturbance term.

In this chapter the statistical theory relevant to the present study is outlined without proof of the mathematical relationships employed. In section 3.2 the theory of Least Squares is presented together with its assumptions and properties and tests of significance of its estimates. Section 3.3 introduces the subject of Econometrics by discussing some departures from the Least Squares assumptions, together with a brief description of the use of Dummy Variables. In section 3.4 the question of simultaneous relationships and their methods of solution is set out followed by a description of the "Single Equation" method of solution in section 3.5.

3.2. The General Least Squares Model

Least Squares is a commonly used technique in Economics though superceded in some cases by the "Maximum Likelihood" method of estimation where the assumptions of least squares are violated seriously (e.g. in certain cases of observational errors in variables). Where its assumptions are satisfied the least squares tool provides the best Linear, Unbiased estimates, i.e., the estimates are B.L.U.E. After explaining the basic theory of least squares and its assumptions this section will explain in more detail the meaning of its above estimational properties.

In the general linear model the "least squares" method estimates the parameters of a hyperplane which minimizes the sum of squares of differences between the observed values of the variables and the values predicted by that hyperplane under a certain set of assumptions.

3.2.1. Assumptions

Assuming that a linear relationship exists between a variable Y and k-1 explanatory variables $X_2, X_3, \ldots X_k$ and a disturbance term u and if we have a sample of n observations on Y and the X's we can write

$$Y_i = \beta_1 + \beta_2 X_{2i} + \ldots + \beta_k X_{ki} + U_i, \quad i = 1, 2, \ldots, n \qquad [3.2.1]$$

The β co-efficients and the parameters of the probability distribution function of u are unknown and it is required to estimate these unknowns. The n equations of [3.2.1] can be converted to matrix notation conveniently as follows

$$Y = X\beta + U \qquad [3.2.2]$$

where

$$Y = \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ \vdots \\ Y_n \end{bmatrix} \qquad X = \begin{bmatrix} 1 & X_{21} & \cdots & X_{k1} \\ 1 & X_{22} & \cdots & X_{k2} \\ \vdots & & & \vdots \\ 1 & X_{2n} & \cdots & X_{kn} \end{bmatrix}$$

$$\beta = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \vdots \\ \vdots \\ \beta_k \end{bmatrix} \qquad U = \begin{bmatrix} U_1 \\ U_2 \\ \vdots \\ \vdots \\ \vdots \\ U_n \end{bmatrix} \qquad [3.2.3]$$

The co-efficient of the intercept term is β_1 and hence a column of units is used in the X matrix to represent this variable.

The problem becomes statistical when we make the following assumptions

$E(U) = 0$ [3.2.4a]

$E(UU') = \sigma^2 I_n$ i.e., $E(U_i^2/\text{any set of } X) = \sigma^2$ [3.2.4b]

X is a set of fixed numbers [3.2.4c]

X has a rank $k<n$ [3.2.4d]

Assumption [3.2.4a] merely states that the U_i are random variables with zero mean or expected value while [3.2.4b] means the variance - covariance matrix of the U_i has ^{2} on the main diagonal and zero everywhere else or more directly that the U_i have homoscedastic properties and are pairwise uncorrelated. The X matrix being a set of fixed numbers in [3.2.4c] is another way of saying that in repeated sampling the sole source of variation in the Y vector is variation in the U vector. However this assumption can be relaxed as can be seen later in section 3.3. Assumption [3.2.4d] presupposes a non-singular X'X matrix which has an inverse. This excludes the possibility of any linear functional relationship between any of the variables in X or more compactly it assumes no perfect intercorrelation.

3.2.2. Least Squares Estimates If $\hat{\beta}$ represents a vector of estimates of β then the model becomes

$$Y = X\hat{\beta} + e \qquad [3.2.5]$$

where e is a column vector of n residuals which differs from the u vector in the original model [3.2.2] by showing the total differences between the estimated plane $(Y - X\hat{\beta})$ and the actual observed surface. The problem now consists of finding the value of β which minimizes the sum of squared values of e_i given by

$$e'e = \sum_{i=1}^{n} e_i^2$$

Equation [3.2.5] gives

$$\begin{aligned} e'e &= (Y - X\hat{\beta})'(Y - X\hat{\beta}) \\ &= Y'Y - \hat{\beta}'X'Y + \hat{\beta}'X'X\hat{\beta} - Y'X\hat{\beta} \\ &= Y'Y - 2\hat{\beta}'X'Y + \hat{\beta}'X'X\hat{\beta} \qquad [3.2.6] \end{aligned}$$

since $\hat{\beta}'X'Y$ and $Y'X\hat{\beta}$ are each scalars. Differentiating this with respect to $\hat{\beta}$ and equating the result to zero yields an extreme point

$$\frac{\partial(e'e)}{\partial\beta} = -2X'Y + 2(X'X)\beta = 0 \qquad [3.2.7]$$

Therefore $\hat{\beta} = (X'X)^{-1}X'Y$

Since $|X'X| \neq 0$ by assumption [3.2.4d].

Assuming the second order conditions are met this value of $\hat{\beta}$ minimizes the sum of squared residuals.

To demonstrate that this fundamental result of least squares give estimates that are B.L.U.E. we begin by expressing $\hat{\beta}$ as a function of the true β, X and the U vector of unknown disturbances and thus find the mean and variance of the estimators. Substituting Equation [3.2.2] into [3.2.7] gives

$$\hat{\beta} = (X'X)^{-1}X'(X\beta + U)$$

$$= \beta + (X'X)^{-1}X'U \qquad [3.2.8]$$

Since $(X'X)^{-1}(X'X) = I_k$. Taking the Expected Value of both sides Equation [3.2.8] yields the mean of $\hat{\beta}$'s distribution as follows

$$E(\hat{\beta}) = \beta + (X'X)^{-1}X'(EU)$$

$$= \beta \qquad [3.2.9]$$

by assumptions[3.2.4a] and [3.2.4c] above. This establishes the unbiased property of the least squares estimators. The variance of $\hat{\beta}$ is found as follows:

Equation [3.2.8] gives

$$\hat{\beta}-\beta = (X'X)^{-1}X'U$$

Thus

$$\text{VAR }(\hat{\beta}) = E(\hat{\beta}-\beta)(\hat{\beta}-\beta)'$$

$$= E(X'X)^{-1}X'UU'X(X'X)^{-1}$$

$$= (X'X)^{-1}X'E(UU')X(X'X)^{-1}$$

Since $(ABC)' = C'B'A'$ and $(X'X)^{-1}$ is symmetric as $(X'X)$ is a symmetric matrix. Thus

$\text{VAR }(\hat{\beta}) = (X'X)^{-1}X'\sigma^2 I_n X(X'X)^{-1}$ by assumption [3.2.4b]

$$= \sigma^2 (X'X)^{-1} \qquad [3.2.10]$$

To show that this variance is minimal (i.e., to establish the "best" part of our earlier statement) we introduce a new unbiased estimator of β, $\hat{\beta}^*$ and see if this estimator can have a smaller variance than our original least squares estimator $\hat{\beta}$. So consider

$$\hat{\beta}^* = (X'X)^{-1}X'Y + AY \qquad [3.2.11]$$

where A is a known kxn matrix of fixed constants

$$E(\hat{\beta}^*) = \beta = E[(X'X)^{-1}X'Y] + E(AY)$$

$$= \beta + E[A(X\beta + u)]$$

using Equation [3.2.2]

therefore $E[A(X\beta + u)] = 0$

therefore $AX\beta = 0$ for all β [3.2.12]

because $E(Au) = 0$ by assumption [3.2.4a]

Equation [3.2.11] gives

$$\hat{\beta}^* = (X'X)^{-1}X'(X\beta + u) + A(X\beta + u)$$

$$= \beta + (X'X)^{-1}X'u + Au \quad \text{by Equation [3.2.12]}$$

therefore $\beta^* - \beta = [(X'X)^{-1}X' + A]u$

$$\mathrm{VAR}\ (\hat{\beta}^*) = E\{[(X'X)^{-1}X' + A]uu'[(X'X)^{-1}X' + A]'\}$$

$$= [(X'X)^{-1}X' + A]\sigma^2 In[(X'X)^{-1}X' + A]$$

$$= [(X'X)^{-1}X'X(X'X)^{-1} + (X'X)^{-1}X'A' + AX(X'X)^{-1} + AA']\ \sigma^2$$

$$= [(X'X)^{-1} + AA']\ \sigma^2 \quad \text{by Equation [3.2.12]}$$

But the main diagonal of AA' is positive since

$$\sum_{i=1}^{n} a_i^2 \geq 0$$

$$\text{VAR } \hat{\beta}^* > \text{VAR } \hat{\beta}$$

Therefore $\hat{\beta}$ has minimum variance and is therefore "best". Also it is seen that $\hat{\beta}$ is "linear" in the sense that it is linear in the Y's. Hence the least squares estimates are B.L.U.E.

To further support the argument regarding the "goodness" of the least squares method we refer to R. A. Fisher's method of maximum likelihood. Here the distribution function of the sample is calculated as the joint distribution function of the sample observations. Then this function is maximized, which is the same as maximizing the likelihood of getting a particular sample. If we assume that the u_i are normally, independently and identically distributed the likelihood function becomes

$$L = \frac{1}{(2\pi\sigma^2)^{n/2}} \exp. \frac{(-u'u)}{2\sigma^2} = \frac{1}{(2\pi\sigma^2)^{n/2}} \exp. \frac{[-(Y - X\beta)'(Y - X\beta)}{2\sigma^2} \qquad [3.2.13]$$

Maximizing the likelihood with respect to β is equivalent to choosing $\hat{\beta}$ to minimize the sum of squares $(Y - X\beta)'(Y - X\beta)$. But this is the least squares criterion already shown by Equation [3.2.7]. Thus we now see that least squares method gives B.L.U.E. and also maximum likelihood estimates.

To round off the discussion an estimator must be found for σ^2 and the multiple correlation co-efficient is introduced. Mention must also be made of the effect of changing from actual original data to deviations from arithematic means.

Using Equation [3.2.2] and [3.2.5] gives

$$\begin{aligned} e &= Y - X\hat{\beta} \\ &= X\beta + U - X[(X'X)^{-1}X'(X\beta + U)] \\ &= U - X(X'X)^{-1}X'U \end{aligned}$$

$$= [In - X(X'X)^{-1}X']U \qquad [3.2.14]$$

letting $X(X'X)^{-1} = F$

and $In - F = M$

It is seen that $M^2 = (I - F)(I - F) = I - F$

because $F = X(X'X)^{-1}(X'X)(X'X)^{-1}X' = X(X'X)^{-1}X' = F$

Since $M' = M$, M is a real symmetric idempotent matrix.

Thus $e'e = U'M'MU = U'MU$

$$E(e'e) = \sigma^2 tr\ M$$

$$= \sigma^2 tr\ (In - X(X'X)^{-1}X')$$

$$= \sigma^2[trI - tr.\ X(X'X)^{-1}X']$$

$$= \sigma^2[n - tr.\ (X'X)(X'X)^{-1}]$$

$$= \sigma^2[n - tr.\ (X'X)(X'X)^{-1}]$$

$$= \sigma^2(n - k) \qquad [3.2.15]$$

$\frac{e'e}{n-k}$ is an unbiased estimator for σ^2.

It can easily be shown (15, p.113) that changing from actual variables to deviations from arithemtic means causes no change in what has seen said so far. Since the regression used in this study is done with data in deviation form the remainder of the discussion will confine itself to this case.

The multiple correlation co-efficient is a summary statistic measuring the proportion of total variance accounted for by the linear relation fitted. It can readily be computed from a regression analysis as follows:

Total sum of Squares = $Y'Y$

Residual unexplained sum of squares = $e'e$

Sum of squares explained by the linear effect of the variables used in the regression $= Y'Y-e'e$

But Equation [3.2.6] shows that

$$e'e = Y'Y = 2\hat{\beta}'X'Y + \hat{\beta}'X'X\hat{\beta}$$

$$= Y'Y = 2\hat{\beta}'X'Y + \hat{\beta}'(X'X)(X'X)^{-1}X'Y$$

$$= Y'Y - \hat{\beta}'X'Y$$

$$Y'Y-e'e = \hat{\beta}'X'Y \qquad [3.2.16]$$

= Sum of squares due to regression

The square of the correlation co-efficient is known as the "Co-efficient of Determination" and is defined by

$$R^2{}_{1,\,2,\,3,\,\ldots\,k} = \hat{\beta}'X'Y/Y'Y \qquad [3.2.17]$$

where $R_{1,\,2,\,3,\,\ldots\,k}$ is the multiple correlation co-efficient. A simple correlation co-efficient between two variables is a measure of the proportion of variance of the dependent variable that is due to the independent variable. It can be derived from the two regression co-efficients between the two variables by taking their product. Its square is also been called the co-efficient of determination and will be used later in this study in the Statistical Analysis section to serve as a measure of the predetermined status of the Consumption Variable.

3.2.3. Tests of Significance Having solved the problem of estimation there remains the question of testing the significance of the resulting estimates. This is usually done by setting up hypotheses concerning the values of the parameters, substituting the value(s) of the estimate(s) concerned into a function whose distribution is known under that hypothesis and accepting or rejecting the hypothesis depending on whether or not the probability of occurrence of the resulting value of test statistic exceeds an arbitrarily fixed level.

In this sub-section 3.2.3 details of derivation of test statistics and their distributions are omitted. However, since one additional important assumption in addition to those of sub-section 3.2.1 is used, it should be mentioned. This assumption is that the U_i have a normal distribution for i = 1, 2, . . ., n

$$\hat{\beta} \text{ is } N[\beta,\ \sigma^2(X'X)^{-1}] \qquad [3.2.4e]$$

From this the practical test procedures set out below are derived following Johnston (24, pp. 117-134).

To test the significance of all the slope co-efficients in β the "null" hypothesis (Ho) is as follows:

$$\text{Ho:}\quad \beta_2 = \ .\ .\ .\ = \beta_k = 0$$

It can be shown (Johnston, 24, pp. 118-134) that the following test statistic has an F distribution with k-1, n-k degrees of freedom under Ho.

$$F = \frac{R^2/k-1}{(1-R^2)/n-k} \qquad [3.2.18]$$

Where R is the multiple correlation co-efficient. Published tables of values for F, corresponding to each level of probability and by different degrees of freedom are available (Ostle, 33). If the value of F exceeds the point where the probability is arbitrarily considered low (say .05 or .01) then the null hypothesis is rejected and the set of co-efficients are taken to be significant at that level of probability.

Similarly to test null hypotheses that one model is not an improvement over another model it can be shown that in certain cases the following statistic is distributed as F with M_1, M_2 degrees of freedom.

$$F(M_1, M_2) = \frac{(S_\omega^\wedge - S_\Omega^\wedge)M_2}{S_\Omega^\wedge M_1} \qquad [3.2.19]$$

where $S_\omega^\wedge$ is the sum of squared residuals of the more restricted function and $S_\Omega^\wedge$ is the sum of squared residuals of the more general case and M_1 and M_2 are degrees of freedom derived as follows:

M_1 the degrees of freedom for the numerator expression is derived by taking the difference of degrees of freedom under the more restricted function and those of the more general case. M_2 is the degrees of freedom of the more general case being tested. The degrees of freedom of any function is derived by subtracting the total number of parameters being estimated from the total number of observations or in previous notation as follows:

$$\text{degrees of freedom of function } j = n_j - k_j \qquad [3.2.20]$$

assuming no further restrictions are placed on the estimates. Again here rejecting the null hypothesis means accepting an alternative hypothesis of significant improvement when using the less restricted model.

Finally a test of significance of the individual co-efficients is necessary. The null hypothesis is as follows:

$$\text{Ho:} \quad \beta_i = 0 \qquad i = 1, 2, 3, \ldots, k$$

and the following test statistic which is distributed as "t" with n-k degrees of freedom is used

$$t = \frac{\hat{\beta}_i - \beta_i}{S\sqrt{a_{ii}}} \qquad [3.2.21]$$

Where a_{ii} is element corresponding to x_i in the principle diagonal of $(X'X)^{-1}$ and S is the estimate of the standard error given by $\sqrt{\frac{e'e}{n-k}}$ in Equation [3.2.15].

3.3. Departures from the General Least Squares Model

The use of least squares in economics is frequently hampered by various violations of its assumptions. Unfortunately due to inability to control the "organism" under study as in the biological and physical sciences the statistical analysis of observed economic data must try to alter that data or alter the statistical analysis to accomodate the departures from the generalized models. When either of these is not possible the analysis is weakened but perhaps not seriously so. In this section the concern is with assumptions [3.2.4b, c, and d] of the previous section. Assumptions [3.2.4b] is violated by the presence of autocorrelated errors; [3.2.4c] by intercorrelation between the independent variables and [3.2.4d] by the use of randomly distributed "X" variables. The latter problem of fixed "X" variables has been taken care of by Graybill (15, pp. 204-206) for the special case where the joint distribution of X and Y is multivariate normal. In this case least squares is shown to yield estimators of the regression co-efficients in the regression of Y on X which have the properties of consistency, efficiency, minimum variance unbiased, and sufficiency. In general also the results of least squares still hold whatever the joint distribution of Y and X because the conditional distribution of Y for given X should still satisfy the assumptions made in the derivation of the tests of significance referred to in the previous section. Thus in this case there is no lack of validity in using the least squares method. However, the same is not true for "Autocorrelation" problems.

3.3.1. Autocorrelation in the residuals This is an ever present problem in Time series economic data. It means that consecutive residuals are not independent and some form of relationship exists between them. Various assumptions have been used to represent this relationship both in testing for its existence and adjusting the analysis and/or data to remove its effects. In practice autocorrelation may be of various forms and caused by different circumstances. For example one may make an incorrect specification of the form of the relationship between the variables or more specifically a linear relation may be specified between Y and X when the true relationship is, say, a quadratic. Even though the disturbance term in the true relation may not be autocorrelated, the quasi-disturbance term associated with the linear relation will contain a term on X^2. If there is any serial correlation in the X values, then the composite disturbance term will be serially correlated especially where the omitted variables tend to move in phase and do not tend to cancel each other in effect.

When using ordinary least squares there are 3 main consequences of autocorrelation.

1. Estimates of α and β are unbiased but the sampling variances of these estimates may be unduly large relative to those achievable by a slightly different method of estimation.

2. If the usual least squares formulae for the sampling variances of the regression co-efficients are applied a serious under-estimate of these variances is likely to be obtained. In any case these formulae are no longer valid nor are the precise forms of the t and F tests.

3. Inefficient forecasts are obtained, i.e., predictions with needlessly large sampling variances derived for the linear model.

Many forms have been assumed in practice for the autoregressive structure, e.g., 1st and 2nd order Markov schemes and limiting cases thereof.

Testing in autocorrelation developed in the 1940's when R. L. Anderson (1) developed a rather roundabout method. This was improved upon by Durbin and Watson (7) in England by use of d as a test statistic for positive autocorrelation and 4-d for negative autocorrelation where d is given by

$$d = \frac{\sum_{t=2}^{n} (Z_t - Z_{t-1})^2}{\sum_{t=1}^{n} Z_t^2} \qquad [3.3.1]$$

Where the Z_t ($t = 1, \ldots, n$) denote the residuals from a fitted least squares regression. However, this test gives inconclusive results for part of its range of values. The same workers (7) also developed a general method of constructing exact tests of serial independence which do not require the use of circular definitions of the serial correlation co-efficient as is done by R. L. and T. W. Anderson (2). However, these exact distributions are obtained at a sacrifice of information which is substantial if the number of observations is small. During this period, Hart and Von Neumann (17) were working on a statistic called the ratio of the mean square successive difference to the variance.

$$\text{Hart - Von Neumann Statistic} = \delta^2/S^2 \qquad [3.3.2]$$

where $\delta^2 = \sum_{i=1}^{n-1} \frac{(X_{i+1} - X_i)^2}{n-1}$

and $S^2 = \sum_{i=1}^{n} \frac{(X_i - \bar{X})^2}{n}$

where subscript i refers to the temporal order of observation X_i. This statistic is related to the Durbin - Watson's statistic by the equation

$$\frac{\delta^2}{S^2} = \frac{n\,d}{n-1} \qquad [3.3.3]$$

In 1942 Hart and Von Neumann (17) tabulated probabilities for the different values of n where n is the number of observations per variable in the equation. The use of these tables (17) in testing is similar to sub-section 3.2.3. Though this test uses less information than the Durbin - Watson test (i.e., the latter takes the number of independent variables into account) its tables are favored by having a wider range of application in sample size.

3.3.2. Intercorrelation Intercorrelation has been called the "General Disease of Economic data". It consists of high correlation between the "X" variables which causes singularity in the X'X matrix rendering it insoluble in the case where the intercorrelation is perfect. It clearly violates assumption [3.2.4d]. However, in practice, the extreme case where one independent variable is an exact linear function of another rarely if ever arises. Even if the correlation is high it is better to use a variable which is a combination of the two intercorrelated variables than to drop one altogether, e.g.,

$$X_c = X_1 + 2X_2 \qquad [3.3.4]$$

where X_1 and X_2 are highly correlated. A special but common case of this is where the investigator has intercorrelation between a trend variable and another independent variable. Here a "deviations from trend" variable is estimated by linear regression as follows:

Let z and w be the two independent intercorrelated variables, w being the trend variable. Assume the model

$$z = \alpha + \beta w + u \qquad [3.3.5]$$

where $E(uw) = 0$

and the other [3.2.4] assumptions hold.

$$\text{Then } \hat{\beta} = \frac{(w'w)^{-1}w'z}{z'z} \qquad [3.3.6]$$

and $\hat{z}$ is calculated corresponding to each of the "z" observations. Then $(z - \hat{z}) = e$ is the required variable. It replaces z in the regression and has the property of being uncorrelated with w by the nature of the least squares method. Intercorrelation leads to large Standard Errors.

3.3.3. Dummy variables   These variables are widely used in economics to allow for qualitative change or for combining data from periods that are believed to be non-homogeneous in a single analysis. For example they have been used to allow for war years as against non-war years in time series analyses. The 0-1 variable is a special case of dummy variables where the variable has a value of 0 in one period and a value of 1 in another period. In a least squares analysis, the regression co-efficient on the 0-1 variable indicates the extent to which the dependent variable is larger or smaller in the second period than in the first, after allowing for the net effect of all the factors specified in the analysis. However, Foote (9) argues as follows:

> "This approach is satisfactory if the only effect of the change in structure is to effect the level of the dependent variable and if the entire adjustment occurs within a single time period. If the change in structure effects the magnitude of the co-efficients or the basic nature of the relationships or the change in structure occurs gradually over time, use of a 0-1 variable is unsatisfactory. Changes that occur gradually over time can be allowed for by the use of a time trend".

However, this does not show the full scope of the use of dummy variables. The 0-1 variable can be used in combination with "slope" variables to describe qualitative slope changes. Also restrictions can be imposed on the dummy variable co-efficients to describe different variations and to ease interpretation. Also the use of dummy variables does not limit itself to 0 and 1 values only.

3.4. Simultaneous Relationships and the Single Equation Approach to Solution

Suppose we have the following system

$$C_t = \alpha + \beta Y_t + u_t \qquad [3.4.1]$$

$$Y_t = C_t + Z_t \qquad [3.4.2]$$

where C, Y, Z, u and t represent consumption expenditure, income, non-consumption expenditure, a stochastic disturbance term and time period respectively.

This system is an example of a Simultaneous System though Equation [3.4.2] is an identity. If we assume Equation [3.2.4a] above we find that

$$E\{ut[Yt-E(Yt)]\} = \frac{1}{1-\beta} E\, Ut^2 \qquad [3.4.3]$$

This violates assumptions [3.2.4e] above and renders ordinary least squares estimates biased and inconsistent. Thus special methods of solution are necessary. The applicability of these methods depend on the identification status of the particular equation being estimated.

3.4.1. Identifiability In his classic paper in 1927 Working (71) explains the concept of identifiability graphically by demonstrating that in statistical demand analysis the problem of defining a demand curve from a series of price-quantity observations needs to consider the relative stability of the demand and supply curves that generated those points. He points out that if the supply curve shifts more than the demand curve then the observations trace out a demand schedule whereas a supply curve results if the reverse is true. If both supply and demand shift simultaneously in equal frequency and extent then neither a demand curve nor a supply curve is obtained. More recently Haavelmo's contribution (16) and the work of Cowles Commission (24) have been primarily responsible for developing the theory to the point where the identification problem has been rationalized in concrete mathematical terms. How to examine an equation in a system for identifiability and what estimational procedures to follow have also been determined. Briefly the theory can be outlined as follows, following Koopmans and Hood (25, p. 115). The variables in a simultaneous system can be grouped into two classes

A. A set of G "true" endogenous variables $\eta_{gt}(g = 1, \ldots, \overset{G}{K})$, whose formation the theory is designed to explain; and

B. A set of K "true" exogenous variables $\xi_{kt}(k = 1, \ldots, K)$, which the theory regards as given for purposes of explaining the formation of the η_{gt} assuming no measurement errors in the variables.

Let the system be as follows:

$$BY_t + \Gamma Xt = Ut \qquad [3.4.4]$$

where B is of order G x G and

Yt is of order G x 1 and represents a vector of G endogenous variables at time t

Γ is of order G x K

Xt is a K x 1 vector of exogenous variables and

Ut is a G x 1 vector of disturbances.

Assuming:

$$|B| \neq 0 \qquad [3.4.5]$$

$$E\,(Ut\ U't + j) = \begin{bmatrix} \sigma^2 11 & \sigma 12 & \cdots & \sigma 1G \\ \sigma 21 & \sigma^2 22 & & \sigma 2G \\ \vdots & \vdots & & \vdots \\ \sigma G1 & \sigma G2 & & \sigma^2 GG \end{bmatrix} \quad \text{for } j = 0$$

$$= 0 \qquad \text{for } j \neq 0 \qquad [3.4.6]$$

Suppose we require to determine the identification status of one equation given by

$$\beta_1 Y_{1t} + \gamma_1 X_{1t} = U_{1t} \qquad [3.4.7]$$

Let $\beta_1 = (\beta_{1\Delta}, 0_{\Delta\Delta})$ [3.4.8]

and $\gamma_1 = (\gamma_{1*}, 0_{**})$ [3.4.9]

Equation [3.4.8] means that G^{Δ} of the y's enter the first equation with non-zero co-efficients and hence $G\text{-}G^{\Delta} = G^{\Delta\Delta}$ enter with zero co-efficient. Similarly Equation [3.4.9] implies that γ_1 consists of $(\gamma_{11}, \gamma_{12}, \ldots, \gamma_{1*}, 0, 0, \ldots, 0)$ where K of the X's enter the equations with zero co-efficients and hence the number of X variables in the system and omitted from this equation is given by

$$K^{**} = K\text{-}K^{*}$$

The conditions for identifiability relate to the rank of a linear homogeneous system which depends on G^{Δ} and K**. These conditions are as follows:

$K^{**} = G^{\Delta}\text{-}1$ as the equation is Just identified

$K^{**} > G^{\Delta}-1$ as the equation is Over identified

$K^{**} < G^{\Delta}-1$ as the equation is Under identified

respectively. [3.4.10]

3.4.2. Methods of solution The commonly used methods of solution of single equations in a system fall into three categories as follows:

A. Indirect least squares (ILS)

B. Least variance ratio (LVR)

C. Two stage least squares (TSLS)

Methods A and B employ the least squares principle combined with adjustment techniques which validate the assumptions of least squares while LVR uses the maximum likelihood criterion of estimation which explains why LVR is also called "Limited information maximum likelihood". The applicability of the three methods depend partially on the identification status of the equation. If under identified no solution is possible while if just identified all methods give identical results. Only methods B and C can be used to solve over identified equations. B and C have a basic similarity in that both methods make use of all the predetermined variables in the model in order to estimate the parameters of a single equation but do not require a detailed specification of the other relations in the model. The LVR estimates are biased in small samples but are consistent.

3.4.3. The single equational model This is a special case of Simultaneous equations methods and is the method employed in this study. It is the case of one endogenous variable being a function of variables all of which are exogenous. The bias present in the ordinary least squares estimates of multi-equational simultaneous equations models and shown in Equation [3.4.3](above) is non-existent in this case. If we merely assume the remainder of the least squares assumptions given in Equation [3.2.4](above) then ordinary least squares (OLS) can be used to estimate the function. If the function itself is the reduced form of an underlying structural equation then the method could be described as a special case of Indirect Least Squares. The function is clearly just identified as

$$(G^{\Delta}-1) = K^{**} = 0$$

Fox has pointed out (11, p. 34) that the pure case of the uniequational complete model may not be found very frequently in practice. However, Wold (69, p. 39) gives an indication of the size of the bias associated with the least squares estimates of equations belonging to a simultaneous system by employing his Proximity theorem. Fuller (13, p. 40) gives a rather lucid version of this theorem as follows:

> "Suppose that a variable X is treated as exogenous when in fact it is mutually determined (i.e., when it is not independent of the residual). The bias is a function of the relative magnitude of the error variance and the correlation between the error and X. For the one variable case Wold illustrates this in the following manner. Given $Y = \beta X + Z^*$ the true relationship, and $y = bx + Z$ the observed, then:
>
> $$E(b) = \frac{E(X\ Y)}{E(X^{2})} = \beta + \frac{E(X\ Z^*)}{E(X^2)} = \beta + r(X\ Z^*)\ \frac{\sigma\ Z^*}{\sigma\ (X)}$$
>
> Where $r(XZ^*)$ is the correlation between X and Z^*. Thus if $r(XZ^*)$ is small and $\frac{\sigma\ (Z^*)}{\sigma\ (X\ )}$ is small then the product (the bias) is small

> of the second order. The bias approaches zero just as the regression of Y on X approaches the regression of X or Y as the correlation between X and Y approaches 1".

The advantages of using the least squares method lies in its ease of computation. The alternative is to consider some of the exogenous variables in the model as endogenous and simultaneously determined with the original endogenous variable. One of the more expensive methods in the sub-section 3.4.2 would then be necessary. In this study the single equation model will be used to estimate the reduced form of the structural demand functions. The choice of variables and the arguments for treating all of them except one as exogenous will be primarily economic in nature though the short time period (one quarter) and some empirical calculation of correlation co-efficients will also support the case. The relatively inexpensive nature of the ordinary least squares computations allows the investigation of a greater number of assumptions and hypotheses.

In this chapter the statistical theory has been set out objectively without applying it to this study. The next chapter attempts to do this.

CHAPTER IV. ANALYTICAL PROCEDURE

4.1. Introduction

In the previous two chapters the theoretical considerations relevant to this study of demand are described. This chapter sets out, in approximate chronological order, details of the procedure followed in performing the research. Besides describing the actual manipulation and computation operations involved Chapter IV also sets out the theoretical framework applied together with its underlying assumptions. The theory developed in Chapters II and III is applied in the present chapter to yield the results shown in Chapter V just as the theoretical framework shown in section 4.2 of this chapter will be applied to the data given in section 4.3 giving rise to the statistical analysis of sections 4.4 and 4.5.

4.2. Theoretical Framework

This section covers the first stage in the research project. The basic variables to be used are described and some anticipated interrelationships stated so that the method of analysis can be explained. Also these models are specified to represent the different demand curves and to permit testing of the hypotheses set out in Chapter I.

4.2.1. The variables These fall into the following classes

A. Retail prices
B. Civilian consumption
C. Total production
D. Disposable income
E. Time trend

F. Dummy variables

G. Other artificial variables

H. Other variables

Different sub-sets of these are used to describe demand functions under the different models in the study. Class C however is only used to test for the predetermined status of Class B. The dummy variables are used to account for qualitative quarterly intercept changes in the functions. Only two different kinds of Class G variables are constructed. One is a "deviations of income from trend" variable used to replace the income variable and thus eliminate intercorrelation between the income and time variables in the analysis. The other artificial variable involved is used in the estimation of the logarithmic functions since the "deviations of income from trend" variable can have negative values. The mean of the income variable is merely added to the "deviations from trend" variable and the result is the new "income" variable. The price, consumption and production variables are needed for the four meats whose quarterly demand functions are to be studied, Beef, Pork, Broilers and Mutton and Lamb. Class E are introduced as a measure of sources of continuous systematic variation for which no data are available. Class H consists of variables whose effects are accounted for by deflation of the specified variables in the models. The two main variables in this category are as follows:

1. The general price level and

2. Population

Thus to remove the effects of these Class B was deflated by 2 and Classes A and D by 1.

4.2.2. The models and tests of hypotheses Three different models are used, each imposing different restrictions on the co-efficients and together forming a framework consisting of a two stage decline in restrictions which permits the testing of the dual hypothesis of Chapter I. The time period involved is the quarter year and the period of study extends from the third quarter of 1953 to the fourth quarter of 1966 inclusively. This gives rise to a total of 13-1/2 years of quarterly time series data or 54 observations in all.

Model 1 is the most restrictive model as it does not allow any quarterly fluctuation in the slope or level of the demand function within the year. The structural demand, supply and equilibrium relationships take the following form:

$$_dX_{ij} = \alpha_{*i} + \alpha_{iB}P_{Bj} + \alpha_{iP}P_{Pj} + \alpha_{iM}P_{Mj} + \alpha_{iC}P_{Cj} + \alpha_{iI}I_j + \alpha_{iT}T_j + U_i \quad [4.2.1]$$

$$_sX_{ij} = Z_{ij}$$

$$_dX_{ij} = {_sX_{ij}}$$

where X is per capita quantity consumed; the P's are retail prices; I and T are personal disposable income and time trend respectively and U is the stochastic disturbance term. Subscripts d, s, j, and i represent demand, supply, quarter, and particular meat respectively. Subscripts B, P, M, and C denote beef, pork, mutton and lamb and broilers respectively. The Z's are exogenous variables.

Model 1 using the logarithms of the variables was also fitted. The non-linear form of this model is as follows:

$$_dX_{ij} = \alpha_{*i} P_{Bj}^{\alpha iB} P_{Pj}^{\alpha iP} P_{Mj}^{\alpha iM} P_{Cj}^{\alpha iC} I_j^{\alpha iI} T_j^{\alpha iT} e^{Ui} \quad [4.2.2]$$

By testing the hypotheses regarding quarterly slope and intercept changes using the linear form of Equation [4.2.2] along with the linear model [4.2.1] account is taken of possible non-linearity in the true relationship between the variables. Equation [4.2.2] can be checked against [4.2.1] for fit by comparison of the computed sum of squared residuals for both forms fitted to the same data. This sum of squared residuals for the logarithmic function is obtained by finding the anti-logarithm of the predicted values, then subtracting the actual value and squaring and summing the differences. However, they both will use all the 54 observations of data and since they estimate seven parameters they each have degrees of freedom given by Equation [3.2.20] where $n_j = 54$ and $K_j = 7$. Thus it follows that the degrees of freedom of Model 1 = 54-7 = 47. Model 2 employs the same set of supply and equilibrium relationships but here the intercept is allowed to vary qualitatively by season within the year due to the addition of three quarterly dummy variables to the previous model as follows:

$$
\begin{aligned}
{}_dX_{ij} = {} & \alpha_{*i} + \alpha_{iB}P_{Bj} + \alpha_{iP}P_{Pj} + \alpha_{iM}P_{Mj} + \alpha_{iC}P_{Cj} + \alpha_{iI}I_j + \alpha_{iT}T_j + \\
& \beta_{i1}D_1 + \beta_{i2}D_2 + \beta_{i3}D_3 + U_i \qquad [4.2.3]
\end{aligned}
$$

where subscripts are the same as for Model 1, the D_j is the quarterly dummy variable which assumes a value of 1 in the j^{th} quarter and a value of zero in other quarters. The co-efficients of the dummy variables having fitted Model 2 measure the amount by which the co-efficient of the particular quarter in the subscript differs from the 4th quarter co-efficient where the intercept for the 4th quarter is given by the constant term of the equation. As in Model 1, Model 2 has a logarithmic counterpart which is as follows:

$$_dX_{ij} = \alpha_{*i} P_{Bj}^{\alpha iB} P_{Pj}^{\alpha iP} P_{Mj}^{\alpha iM} P_{Cj}^{\alpha iC} I_j^{\alpha iI} T_j^{\alpha ir} e^{(\beta_{i1}D_1 + \beta_{i2}D_2 + \beta_{i3}D_3 + U_i)} \qquad [4.2.4]$$

In both [4.2.3] and [4.2.4] the number of parameters being estimated is ten and thus the degrees of freedom for this model is 54 minus 10 = 44 since the model uses all the observations as does Model 1.

In Model 3 the same structural relationships, equilibrium identities and supply functions as Model 1 are used but now the analysis is repyeated for each quarter individually. This obviously allows both the intercept and slope to vary by quarter within the year. The model can be shown as follows:

$$_dX_{ij} = \alpha_{*ij} + \alpha_{iBj}P_{Bj} + \alpha_{iPj}P_{Pj} + \alpha_{iMj}P_{Mj} + \alpha_{iCj}P_{Cj} + \alpha_{iIj}I_j + \alpha_{iTj}T_j + U_{ij} \qquad [4.2.5]$$

where the subscripts are the same as for Model 1. The non-linear version of Model 3 is given as follows

$$_dX_{ij} = \alpha_{*ij} P_{Bj}^{\alpha iBj} P_{Pj}^{\alpha iPj} P_{Mj}^{\alpha iMj} P_{Cj}^{\alpha iCj} I_j^{\alpha iIj} T_j^{\alpha iTj} e^{Uij} \qquad [4.2.6]$$

Since these models are fitted only to quarterly data the degrees of freedom vareys during the year due to a differing number of observations between the first two quarters and the last two. Thus for quarters 1 and 2 the degrees of freedom is 13 - 7 = 6 and is 14 - 7 = 7 for the other two quarters.

Thus three basic models will be employed in the analysis, the purpose of which is to fit variables linearily and non-linearily to a common set of data with the twofold purpose of

A. Testing the following hypotheses

1. The level of the demand function is constant by quarter within the year (i.e., Model 2 is not superior to Model 1).

2. The slope of the demand function does not vary among seasons of the year (i.e., Model 3 is not superior to Model 2).

and B. Examining selected functions for non-linearity and subsequently deriving elasticities and flexibilities based on the four equations of best fit to the data.

4.2.3. Tests of hypotheses Having acquired the models suitable for the purpose it is a straightforward procedure to test the hypotheses. The number of restrictions on the parameters diminishes from Model 1 to Model 3. In Model 1 neither the slope nor the intercept is allowed to vary while in Model 2 the intercept can change. In Model 3 both intercept and slope are allowed to shift among quarters. The equations for the three models therefore are tested for homogeneity with each other. Model 2 is tested against Model 3 to test the hypothesis that all the slopes of regression co-efficients on the independent variables are the same but the intercepts vary. Similarly, Model 1 was tested against Model 2 to test the hypothesis that the intercepts as well as the slopes are equal for all 4 quarters. The test used is based on the F-test given in Equation [2.2.19] of the previous chapter where the more restricted function is Model 1 when testing hypothesis 1 and Model 2 when testing hypothesis 2. In addition to Equation [2.2.19] somewhat more detail is required for calculating F for the test of homogeneity between Models 2 and 3 because of the fact that Model 3 has four different equations for every one of Model 2. Thus in this case the F-test statistic of Equation [2.2.19] is calculated as follows:

$$F(M_1 M_2) = \frac{(S_{\omega}^{\wedge} - S_{\Omega}^{\wedge})M_2}{S_{\Omega}^{\wedge}\, M_1}$$

where $S_{\omega}^{\wedge}$ is the sum of squared residuals of the more restricted function which in this case is Model 2 and is given by the following

$$S_{\omega}^{\wedge} = \sum_{i=1}^{54} e_i^2$$

where the e_i are the residuals from fitting Model 2 to the data in Equation i.

$S_{\Omega}^{\wedge}$ is the sum of squared residuals from the more general case which is Model 3 in this case and it is calculated using the formula

$$S_{\Omega}^{\wedge} = \sum_{i=1}^{13} \sum_{j=1}^{2} e_{ij}^2 + \sum_{i=1}^{14} \sum_{j=3}^{4} e_{ij}^2$$

where e_{ij} is the residual for quarter j in year i. M_1 is the degrees of freedom for the numerator expression and is derived by taking the difference between the degrees of freedom under the more restricted function (Model 2 here) and those of the more general case being tested (Model 3 in this example).

In this example

$$\begin{aligned} M_1 &= \text{d.f. Model 2 less d.f. Model 3} \\ &= (N-K) \text{ less } \sum_{i=1}^{4} (N_i - K_i) \end{aligned}$$

= 44 less 26

= 18

M_2 is the degrees of freedom of the more general case being tested. In this case M_2 = 26.

As explained in section 3.2.3 in the previous chapter, if a small F value is obtained (or smaller than a value corresponding to an arbitrarily low probability level) then the hypothesis of no difference between the models is accepted at that probability or significance level and the alternative hypothesis of the added restrictions in the more restricted function (Model 2 here) being valid is rejected. The opposite is true for a significantly high value of F.

For testing the overall significance of the co-efficients of each equation individually the F-test given by Equation [3.2.18] in the previous chapter is used. Also the individual estimated parameters are tested for significance using the t test given by Equation [3.2.21].

4.3. The Data

Quarterly time series data collected for the period 1949-1966 inclusive are set out in Appendix under the following headings:

A. All items retail consumer price index (1957-1959 = 100)

B. Per caput personal disposable consumer income in current dollars deflated by series A

C. Retail price per pound of beef, pork, broilers and mutton and lamb deflated by series A (dollars)

D. Per caput consumption of beef, pork and Mutton and Lamb (lbs.) from commercial sources

E. Per caput total (farm and commercial) consumption of beef, pork, broilers and mutton and lamb (lbs.)

F. Total civilian consumption and production of beef, pork and mutton and lamb (millions of lbs.)

Table 4.3.1 gives the original sources for this data, the part of each time series contributed by each source and what adjustments were necessary (if any) to achieve the final form as shown in Appendix 1.

In general the price data were weighted average prices per pound of particular cuts at various specific locations while the consumption data were civilian consumption in the U. S. calculated on a "disappearance" basis and divided by Total Civilian U. S. population. In most cases original data series were not complete for the period under study (1949-1955). Thus series had to be found which overlapped for a number of years before they could be claimed to be homogeneous or alternatively before adjustments could be made to make them "fit" each other.

Beef and Lamb prices were for cuts from choice grade carcasses while Pork prices consisted of weighted average price of hams, bacon, loins, sausage, butts, spareribs and bacon squares. In all three cases the different series overlapped sufficiently well to allow "splicing" of the data from the different sources. However, the two price series for Broilers did not oblige on this regard. These prices are quoted for ready to cook chickens. The later series (1957-1966)(Series I) overlapped the earlier (1949-1960)(Series II) by fifteen quarters (1957 Qtr. I to 1960 Qtr. III). For each of the fifteen pairs of observations (one observation from each series during period of overlap) the difference between the two was taken. Correlation co-efficients (r) between this series of differences and each of the two "generating" series were calculated and found

Table 4.3.1. The data: original sources and manipulation.

Data heading[a]		Source reference	Period covered[b]	Adjustments[c]
A.		(47)	1949 to 1962	
		(41)	1960 to 1966	
B.		(42, p. 52)	1949 to 1966	Deflate[d]
C.				
	Beef	(63, pp. 12-14)	1949 to 1964	Deflate[d]
		(60, p. 10)	1965	Deflate[d]
		(61, p. 9)	1965	
	Pork	(63, pp. 13-15)	1949-1965 (3rd Qtr)	Deflate[d]
		(61, p. 9)	1966 (4th Qtr)	Deflate[d]
	Mutton &	Private communication[e]	1949 to 1965	Deflate[d]
	Lamb	(61, p. 9)	1966	
	Broilers	(48, p. 16)	I. 2nd Qtr 1949 - 3rd Qtr 1960	Adjust[f]
		Private communication[e]	II. 1957-1966	

[a]These headings are given in the text on Page 41 and 42.

[b]Part of time series data found in the source referred to.

[c]Manipulation of data before incorporation into the data was shown in Appendix 1.

[d]Deflate by data series given by data under A above.

[e]Henry T. Badger. United States Department of Agriculture. Marketing Economics Division. Private communication. 1967.

[f]This adjustment was necessary as the overlapping data did not match.

Table 4.3.1. (Continued)

Data heading[a]	Source reference	Period covered[b]	Adjustments[c]
D.			
Beef, Pork & Mutton & Lamb	(49, pp. 30-41)	1949 to 1956	
	(50, pp. 285-288)	1957	
	(51, pp. 139-140)	1958	
	(52, pp. 139-140)	1959	
	(53, pp. 139-140)	1960	
	(54, pp. 136-137)	1961	
	(55, pp. 290-291)	1962	
	(56, pp. 148-149)	1963	
	(57, pp. 147-149)	1964	
	(58, pp. 146-147)	1965	
	(59, pp. 147-148)	1966	
E.			
Beef & Pork	Private communication[g]	1949 to 1959	
	(50, pp. 285-288)	1957	
	(51, pp. 139-140)	1958	
	(52, pp. 139-140)	1959	
	(53, pp. 139-140)	1960	
	(54, pp. 136-137)	1961	
	(55, pp. 290-291)	1962	
	(56, pp. 148-149)	1963	
	(57, pp. 147-149)	1964	
	(58, pp. 146-147)	1965	
	(59, pp. 147-148)	1966	
Mutton & Lamb	(49, pp. 36-38)	1949 to 1955	
	(65, p. 60)	1956	
	(50, pp. 285-288)	1957	
	(51, pp. 139-140)	1958	
	(52, pp. 139-140)	1959	
	(53, pp. 139-140)	1960	
	(54, pp. 136-137)	1961	
	(55, pp. 290-291)	1962	
	(56, pp. 148-149)	1963	
	(57, pp. 147-149)	1964	
	(58, pp. 146-147)	1965	
	(59, pp. 147-148)	1966	

[g]B. G. Stanton, Professor of Farm Management, New York State College of Agriculture, Cornell University, Ithaca, New York. Data used in a previous study and is described on Page 46. Private communication. 1967.

Table 4.3.1. (Continued)

Data heading[a]	Source reference	Period covered[b]	Adjustments[c]
Broilers	Private communication[g]	1949 to 1959	
	Private communication[h]	1960 to 1964	
	(62, p. 27)	1965 to 1966	
F. & G.	(50, pp. 285-288)	1957	
	(51, pp. 139-140)	1958	
	(52, pp. 139-140)	1959	
	(53, pp. 139-140)	1960	
	(54, pp. 139-140)	1961	
	(55, pp. 139-140)	1962	
	(56, pp. 139-140)	1963	
	(57, pp. 139-140)	1964	
	(58, pp. 139-140)	1965	
	(59, pp. 139-140)	1966	

to be significantly high (0.83 and 0.87). This high correlation indicated the use of a regression model to adjust one series to make it fit the other. To facilitate use of the resulting homogeneous data series with new data in future years the later Series II was the independent variable and the earlier Series I was regressed linearly on II. Using the estimated parameter for intercept and slope Series $\hat{I}$ was predicted and used in place of Series I for the period 1949 Qtr 2 to 1957 Qtr 4. The predicted data for the period of overlap was compared with the actual data and they were found to be practically identical. There then remained the price of broilers for the first quarter of 1949, to be estimated. This was estimated by extrapolation using least squares prediction from the preceeding nine prices and time.

The consumption data all had sufficient sources. One set of consumption data included farm and commeriial consumption whereas the other set included non-farm consumption only. This data formed a homogeneous set

[h]Source: Soliman (3F). Data described on Page 46.

though coming from a heterogeneous mass of sources as seen in Table 4.3.1. The per capita figures are computed by dividing total consumption by total civilian population. As mentioned at the end of the last section Total Consumption and Production originating from both farm and Commercial production were recorded from 1957 to the end of the period under study. These data were not available for Broilers and so had to be dispensed with. Also the broiler per capita consumption data deserve special mention due to their partial unavailability in published form. The two sources referred to in Table 4.3.1 for broiler consumption were used to fill this gap which extended from 1949 to 1964. These data from 1949 to 1959 represent production and poultry slaughter statistics corrected for changes in storage, export and import transactions, etc. and were used in a previous study by Stanton (38).

The data for the 1960-1964 period were used in a previous study by Soliman (37) and represent the quantity of broiler chicks hatched, adjusted for mortality, multiplied by average weight per bird, advanced two months, multiplied by a factor of 0.72 and adjusted for storage and exports.

Because of similar unavailability of data for the commercial broiler Consumption series the same set of broiler consumption data was used for both sets of Consumption data. Finally, the all items consumer price index (1957-1959 = 100) and personal disposable consumer income in current dollars were available in complete form in the sources shown in Table 4.3.1.

4.4. Justification of the Analytical Method

The "single equational model" as used in this study employs ordinary least squares to estimate the reduced form of the structural demand functions outlined in the models of section 4.2.2. The reduced form equations express the price variable (in the dependent position) as a function of consumption, income, time and sometimes dummy variables which are in the independent position. This orientation of the variables is demanded by the method of solution used because price is assumed to be the only endogenous variable in the system by which it is determined while all the other variables are assumed to be exogenous or determined outside of the system. The observations are assumed to be generated by the simultaneous interaction of a stationary demand curve, and a shifting vertical supply curve. The supply thus causes the prices while being casually independent or predetermined itself. However, as Baumol (4, pp. 226-228) has explained, what renders the demand curve identifiable is the fact that supply is determined by variables which do not appear in the demand function, causing the supply curve to shift independently of the demand curve.

Empirically the assumptions have to be examined in the light of knowledge of the particular commodities whose demand is being studied as follows:

In general production of meat can be broken down into its various disappearance channels as follows:

$$\text{T.P.} = \text{T.C.C.} + \text{T.N.I.C.} + \text{T.N.E.} + \text{M.T.} \qquad [2.3.1]$$

where T.P. is total production of meat

T.C.C. is total civilian consumption of meat

T.N.I.C. is total net inventory change

T.N.E. is total net exports and

M.T. is total military takings.

The left hand side of identity [2.3.1] can be taken to be predetermined or independent of current price since in all cases decisions determining the T.P. are made prior to the current period since the length of the production period exceeds a quarter year even for broiler production. Fox (10, pp. 30-33) has argued that farm production of beef and pork can be considered largely predetermined. Most of his arguments hold even more for the shorter period of a quarter. The total production period for hogs approaches a year and the production period for beef is even longer. Fox (10, p. 39) found that in the case of lamb, from 1927 to 1941, 97% of the variation in production could be explained in terms of predetermined or non-economic variables. The same source (10, p. 49) can be quoted for the case of chickens as follows:

> "As no measurable competition in demand between eggs and chickens is found, the price of eggs may be regarded as uninfluenced by current slaughter of chickens. If prices of eggs and of poultry feeds in the early months of the calendar year are treated as predetermined variables, 69 percent of the observed variation in total slaughter in millions of pounds (dressed weight) of farm chickens can be explained by predetermined non-economic variables".

Farmers are able to vary production within a quarter only by feeding to heavier or lighter weights, by marketing breeding stock or by withholding stock for breeding or additional feeding. These alternatives are partially self balancing. For example, if a high price encourages selling feeder stock in the current period instead of feeding to the previously planned greater weight and selling in the next period then there also will be an incentive to withhold more animals for breeding in anticipation of continued high prices. Thus T.P. of identity [2.3.1] is predetermined. This means that the net effect of the right hand side of the identity is also exogenous. Military takings are a function of the size of the armed forces while imports and exports are generally small relative to total population. Thus only stocks are important and simultaneously determined with production. However, Tolley and Harrell (44, p. 19) have demonstrated that the movement of meat through cold storage seems to be determined by the perishability and ageing process of the meat more than by price. Also at this point a quotation from Fox (10, pp. 12-13) is relevant.

> "Suppose the changes in stocks and in net trade are both small relative to observed changes in consumption and that domestic consumption, accumulation of stocks, and net exports move in the same direction in response to changes in supply. In such cases, changes in domestic consumption can be estimated with considerable accuracy on the basis of changes in supply. If supply is predetermined consumption also can probably be treated as predetermined under such conditions".

Fox (10, pp. 38-39) develops the argument as follows:

> "If the correlation between changes in consumption and changes in farm supply or production is very high ($r^2 = 0.9$ or higher) it will generally be satisfactory to treat estimated consumption as a predetermined variable".

The results of studies on the predetermined status of the meats for the period 1922-41 by Fox (10, pp. 31-49) may be summarized in the following Table 4.4.1.

Fox (10, pp. 41-42) also adds that the arguments for the predetermined status of consumption of competing commodities are the same as for

Table 4.4.1. Summary of correlation studies to establish predetermined status of the consumption variables.

	r^2 Between Domestic Consumption and Production	r^2 Between Production and Predetermined Variables	r^2 Between Domestic Consumption Predetermined Variables
Beef	98	87	85
Pork	93	95	88
Mutton & Lamb	98	97	95
Farm Chickens	88	69	61

the commodity of primary interest in the equation. For the case of beef Fox concludes that if the unexplained 15% of consumption variation is at all significant, the bias introduced by using consumption of beef as an independent variable in a single equation least squares demand function should be less than 5%.

Putting the above evidence together and combining with it updated empirical evidence of a similar kind described in Chapter V establishes the justification for using the consumption variables exogenously. There remains to be shown the exogenous nature of the other variables in the analysis, namely personal disposable income, secular time trend and "0-1" variables. The latter two are obviously exogenous being determined independently by the researcher. Fox (10 p. 40) has argued that the short run variation in farmers income caused by quarterly farm gate price changes is unimportant as follows:

"The regression multiplier analysis is a static one; nevertheless some time must be required in the real world for farmers to make decisions and to spend the money they have received for the commodity".

These are some of the arguments put forward in the literature for the use of the single equational model in this study. All of the above arguments hold with increased force for the shorter period of three months. Also Chapter V will discuss the results of updating Fox's correlation studies between production and consumption which will be done in this piece of research for the 36 quarter period from 1957 to 1966 for the red meats being studied.

4.5. The Analysis

Having collected the quarterly data shown in Appendix 1 and described in the previous section for the period 1949-1966 it was found in a previous work by Ladd (28, p. 838) that price ceilings had been in effect on beef prices from May 1951 to February 1953 and that wholesale ceiling prices were in effect on pork from October 1951 to February 1953. Due to lack of information on how these "ceilings" effected the demand, only data for the period commencing in the third quarter of 1953 to the end of 1966 was used. Thus for this 54 quarter period the reduced form of each of the three models shown in section 4.2 was fitted by the method of ordinary least squares. The non-linear forms were also fitted by the same method applied to the variables in logarithmic form. To avoid intercorrelation between the time and income variables two artificial variables were used to replace the income variable and the analysis repeated. The first of these was a deviations of income from trend variable (see sub-section 3.3.2) which was used when the linear models were fitted. Since this variable had negative values sometimes the second artificial variable was constructed for the logarithmic functions by adding the mean of the income variable (1908.2087) to each observation in the first artificial variable. The non-linear models were then fitted by ordinary least squares on double logarithmic data. The total number of equations fitted was thus 192 or 48 for each of the four commodities whose demand functions are to be studied. Each of these forecasting equations were tested for auto-correlation in the residuals using the Hart-Von Neuman Statistic and intercorrelation between the independent variables in the equations was observed by means of a correlation matrix. All co-efficients were tested both for overall and individual significance at the 5 and 1% levels using F and t tests respectively described in section 4.2 of this chapter. Multiple co-efficients of determination were also extracted for each equation. Then within each of the two regression branches (linear and logarithmic) F-tests of homogeneity were performed (see sub-section 3.2.3 and 4.2.2) to test the two hypotheses of Chapter I. The best models were established in this manner under the linear and non-linear assumptions. When the choice of model for a particular meat was the same under both linear and non-linear assumptions then these assumptions were tested by determining which equations form provided a better fit to the data. This test is identical to the test for non-linearity described in sub-section 4.2.2 for Model 1. This establishes the uniquely best model out of the three linear and three logarithmic models possible. Where the choice of model from the linear and logarithmic equations is not unanimous then both models are selected.

The flexibilities and cross-flexibilities are then computed for the optimal reduced form equations as found above. This is done just as the elasticities and cross-elasticities are computed below on the derived optimal structural equations. These derived optimal structural demand functions, elasticities and cross-elasticities, and flexibilities and cross-flexibilities are computed for each set of optimal equations (i.e., one for linear case and one for the non-linear case) as follows:

Let the optimal set be represented by

$$\underset{\sim}{P} = \underset{\sim}{B}\underset{\sim}{Q} + \underset{\sim}{\Gamma}\underset{\sim}{X} \qquad [4.4.1]$$

where $\underset{\sim}{P}$ is a 4 by 1 vector of Prices

$\underset{\sim}{Q}$ is a 4 by 1 matrix of quantities consumed

$\underset{\sim}{B}$ is a 4 by 4 matrix of co-efficients for the variables in $\underset{\sim}{Q}$

$\underset{\sim}{X}$ is an n by 1 vector of other independent variables

Γ is a 4 by n matrix of co-efficients for the variables in $\underset{\sim}{X}$

The structural set of equations are then given by

$$\underset{\sim}{Q} = \underset{\sim}{B}^{-1}P - B^{-1}\Gamma X \qquad [4.4.2]$$

The direct and cross price elasticities of this set of equations in the linear case are then computed in the following steps

1. Compute $\underset{\sim}{\hat{\bar{Q}}} = \underset{\sim}{B}^{-1}\underset{\sim}{\bar{P}} - B^{-1}\underset{\sim}{\Gamma}\underset{\sim}{\bar{X}}$ [4.4.3]

   where $\underset{\sim}{\bar{Q}}$ represents the predicted mean value of Q corresponding to the means of the structural independent variable vectors P and Q given by $\bar{P}$ and $\bar{Q}$ respectively.

2. Compute the matrix of $\left(\frac{q_{ij}}{p_{ij}}\right)$ which consists of the elements of the $\bar{P}$ vector by the corresponding elements of the $\bar{Q}$ vector.

3. Multiply the elements of $\left(\frac{q_{ij}}{p_{ij}}\right)$ by the corresponding elements of B^{-1}.

The resulting matrix $\frac{q_{ij}}{p_{ij}} \times (b_{ij})^{-1}$ gives the direct and cross-price elasticities of the optimal set of linear demand equations for the four meats. For the logarithmic case this matrix is identical with B^{-1}.

The matrix of direct- and cross-price flexibilities are computed by applying the above 3 steps to the reduced form equations given by Equation [4.4.2] except here the Q's will be interchanged with the P's.

The vector of Income elasticities are computed from Equation [4.4.3] as follows:

Follow steps 1 and 2 above using the Income variable in X instead of P. Then in step 3 replace B^{-1} by the $B^{-1}\Gamma$. The result is a vector of Income elasticities. For the logarithmic equations the income elasticities of demand are the co-efficients of the income variable within $B^{-1}\Gamma$.

CHAPTER V. EMPIRICAL RESULTS

5.1. Introduction

The results of this study can be divided into the eight different regression analyses, one for each box in a three way cross classification table with two sets of consumption data in one direction, two types of income variables in another and finally two types of models (one linear and the other logarithmic) in the third direction. A complete set of results could be described for each one of the eight analyses. This would involve reporting on the fitting of the three models described in Chapter IV making twenty-four equations for each box. Since there is a reason for expecting some of the eight sets of equations to be better representations of the meat demand functions than others, only some will be reported in the present chapter. Since the Income Deviations[1] variable improves the method of analysis by reducing intercorrelation between the independent variables the results using this variable should be superior to those where the original income variable is used. By only using the results of the regressions using the income variable to estimate income elasticities of demand in section 5.4 and by confining the discussion to those regressions using the "income deviations" variable one dimension of the study is dispensed with. Another dimension is removed by addressing the discussion to the set of regressions using the commercial consumption variables. The results of the total consumption case are discussed only as a comparison with the results of the commercial consump-

[1] Income deviations are described in Chapter IV (section 4.5) where they comprise a "Deviations of income from trend variable".

tion case. This is done for each meat individually in section 5.3. In this section a discussion of quarterly fluctuations evident in the fitted equations is followed by the results of the F-tests of homogeneity which are described in section 4.2.3 of the previous chapter. The results of these tests from the logarithmic and linear sets of results are combined to establish a set of equations of superior fit to the data. In section 5.4 the direct and cross price elasticities of demand are calculated from this set of equations by applying the method described previously in section 4.5. Section 5.5 includes a description of the empirical effects of intercorrelation by demonstrating the departure of the analysis using straight income and time variables in place of the variables involved in the emphasized case here. Since the derivation of income elasticities requires the use of the straight income variable this topic is covered in section 5.5. The next section of this chapter reports the results of updating some of the research done by Fox (10) in justifying the use of the single equational model in estimating demand functions for meats.

5.2. Correlation between Production and Consumption

Section 4.4 of the previous chapter states the case for the use of the single equational model in the estimation of the reduced form equations of the annual demand for beef, pork, broilers and mutton and lamb. The production of these meats were assumed to be predetermined. The use of the correlation between production and consumption by Fox to establish the exogenous status of the consumption of the four meats was cited giving the results of this investigation in Table 4.4.7. A similar investigation was performed in this study for the red meats using quarterly data for the period 1957 to 1966. The results are shown in Table 5.2.1 for each quarter individually and for the whole period.

Since the results for Beef and Pork fulfill the condition imposed by Fox (10, pp. 38-39) (i.e., $r^2 = 0.90$ or higher) for annual data consumption can be regarded as predetermined for the meats. However, this condition is only fulfilled for the fourth quarter for Mutton and Lamb. Thus for the other three quarters the analysis may be biased to some extent. For all quarters together the unexplained 15.05 percent (i.e., 1.000 less 0.8495) should introduce a bias of less than 5% when consumption of Mutton and Lamb is considered as predetermined in a single equation least squares demand function (10, pp. 41-42). The predetermined status of broiler consumption was not examined for this period and so this case has to rest on the arguments offered in section 4.4 of the previous chapter.

The consumption data represented total consumption but since the commercial consumption data are so highly correlated with the total consumption data (Shown by Table 5.2.2) the results in Table 5.2.1 hold equally well.

5.3. Results for Individual Meats

Since the choice of model form (i.e., logarithmic or linear) was not the same in all cases the results of fitting both model forms are reported. The tables of this section show the estimated reduced form co-efficients for the case of commercial consumption and "income devia-

Table 5.2.1. Values of r^2 between quarterly civilian consumption and quarterly total production for Beef, Park and Mutton and Lamb for each quarter and for the whole year for the period 1957-1966.

	Beef	Pork	Mutton and Lamb
1st Quarter	0.9888	0.9869	0.8188
2nd Quarter	0.9942	0.9704	0.7884
3rd Quarter	0.9816	0.9585	0.8881
4th Quarter	0.9902	0.9789	0.9163
All Quarters	0.9847	0.9423	0.8495

Table 5.2.2. Correlation between quarterly total consumption and quarterly commercial consumption data (1957-1966).

Meats	r^2
Beef	0.9978
Pork	0.9275
Mutton and Lamb	0.9379

tions" variables. In these tables symbols D_1, D_2 and D_3 are the same as described in sub-section 4.2.2 of the previous chapter; Column headings, Beef, Pork, Mutton and Lambs and Broilers represent commercial consumption of the respective meats; and where shown the sum of squared residuals for the logarithmic equations is computed as explained in section 4.5 of the previous chapter. In these tables, the three models are numbered consecutively as they are fitted in order to Beef, Pork, Mutton and Lamb and Broilers. The form (linear or logarithmic) of the model fitted is indicated by letters (a) and (b) respectively. Model three equations are broken down quarterly by using a numerical subscript and represents the quarter to which the equation refers.

5.3.1. Beef The regression co-efficients of the demand functions fitted, their standard errors, and the significance of their respective co-efficient at the 5 and 1 percent levels are shown in Table 5.3.1 together with various measures of fit of the equations (i.e., R^2, Sum of Squared Residuals, and F-test of overall significance of the variable in each equation). The Hart-Von Neumann statistic is also presented together with its level of significance.

In general, the co-efficients of Beef, Pork, Mutton and Lamb and Broiler consumption variables would be expected to be negative unless dominated by a strong income effect. However, as evidenced by most of the equations in Table 5.3.1 the signs of the broiler and lamb consumption co-efficients are positive even though the co-efficient of the income variable is non-significant in all cases. The per capita consumption rates for mutton and lamb and broilers are very low and, perhaps, the relationship may illustrate similar but independent movements of the three products. The income deviations variable is non-significant throughout indicating a weak income effect.

The quarterly dummy variables of the linear version of Model II do indicate some similarities in intercept between Quarter 1 and 2 and between Quarters 3 and 4. This is based on the similarity (i.e., -2.5399 to -2.5399) of the co-efficients of the first and second quarterly

Table 5.3.1. Estimated Co-efficients for Beef Reduced Form Equations.

		Regression Co-efficients and Their Standard Errors[a]			
Dependent Variables	R^2	Constant Term	D_1	D_2	D_3
Model I					
1(a) P_B	.6575	125.32**			
		10.80			
1(b) P_B	.5582	2.7040**			
		.910			
Model II					
2(a) P_B	.7604	142.10**	-2.3492*	-2.5399	.7522
		10.58	.953	1.296	1.530
2(b) P_B	.6652	2.1513*	- .0141*	- .0285**	- 0186*
		.856	.007	.008	.008
Model III					
$3(a)_1$ P_{B1}	.8966	163.80**			
		21.65			
$3(b)_1$ P_{B1}	.7378	3.1485			
		2.408			
$3(a)_2$ P_{B2}	.8051	144.97**			
		27.31			
$3(b)_2$ P_{B2}	.7536	2.1962			
		2.602			
$3(a)_3$ P_{B3}	.6524	142.84*			
		43.66			
$3(b)_3$ P_{B3}	.5762	1.6301			
		1.970			
$3(a)_4$ P_{B4}	.7365	110.77**			
		28.82			
$3(b)_4$ P_{B4}	.7723	1.8804			
		1.690			

[a]Standard errors are shown directly beneath the co-efficients. ** and * mean significant at the 5 and 1 percent levels of significance respectively.

[b]Residual Sum of Squares are given for all the linear equations and selected logarithmic equations where they are calculated as explained on Page 37.

Table 5.3.1. (Continued)

Dependent Variables	Commercial Consumption Beef	Pork	Mutton and Lambs	Broilers	Income Deviations
Model I					
1(a) P_B	-2.9344**	- .2121	.0181	1.5955*	.0014
	.450	.340	3.844	.676	.010
1(b) P_B	- .5285**	.0756	.0111	.2072**	- .1080
	.113	.086	.067	.060	.293
Model II					
2(a) P_B	-3.8174**	- .5624	5.1398	1.4052	.0158
	.482	.336	3.747	.861	.009
2(b) P_B	- .6461**	- .0730	.0775	.2828**	.1501
	.108	.091	.069	.061	.281
Model III					
$3(a)_1$ P_{B1}	-4.4262**	-1.2385	6.8695	- .8308	.0169
	.916	.641	6.482	2.517	.020
$3(b)_1$ P_{B1}	- .6372	- .2795	.0835	.1000	- .0683
	.288	.243	.161	.180	.792
$3(a)_2$ P_{B2}	-4.3286*	-1.0732	14.7823	1.3061	.0222
	1.318	1.258	16.323	2.792	.031
$3(b)_2$ P_{B2}	- .7987*	- .3586	.1495	.2271	.2854
	.266	.344	.236	.261	.820
$3(a)_3$ P_{B3}	-3.8585	.0680	- .3271	.6576	.0142
	1.683	1.165	10.857	2.426	.024
$3(b)_3$ P_{B3}	- .4986	.0879	.0462	.2951	.1897
	.275	.262	.168	.176	.627
$3(a)_4$ P_{B4}	-2.6598	- .1594	6.0163	2.6120	.0073
	1.237	.634	8.987	2.574	.023
$3(b)_4$ P_{B4}	- .6099*	.0279	.1435	.3959*	.1682
	.215	.151	.140	.156	.574

Table 5.3.1. (Continued)

Dependent Variables	Time	Sum of Squared Residuals[b]	F-Ratio	Hart - Von Neumann
Model I				
1(a) P_B	.2626** .081	261.85	15.038**	1.1521**
1(b) P_B	- .0084 .017		9.898**	.8347**
Model II				
2(a) P_B	.4030** .113	183.20	15.515**	1.0037**
2(b) P_B	- .0145 .018	249.04	9.713**	.8084**
Model III				
$3(a)_1$ P_{B1}	2.7865* 1.092	26.72	8.672**	2.5566
$3(b)_1$ P_{B1}	.0602 .066		2.813	1.9496
$3(a)_2$ P_{B2}	2.0346 1.515	49.19	4.130	2.1115
$3(b)_2$ P_{B2}	.0460 .102		3.058	1.8667
$3(a)_3$ P_{B3}	1.8118 1.556	44.25	2.190	1.8584
$3(b)_3$ P_{B3}	- .0471 .071		1.586	2.2602
$3(a)_4$ P_{B4}	.5611 1.261	32.94	3.260	2.3767
$3(b)_4$ P_{B4}	- .0740 .057		3.956*	2.2849

dummy variables and in turn the small deviation between the intercept of Quarter 4 (142.10) and that of Quarter 3 as indicated by the non-significant co-efficient of the third quarterly dummy variable which is 0.7522 for the linear model. The logarithmic model does not display similar "pairing" but this equation is not as good a fit as the linear one as displayed by their differing residual sum of squares.

This is supported by the findings of Logan and Boles (30, p. 1055) who found similar pairing of co-efficients. Stanton (38) found in contrast that semi-annual data would best pair Quarters 2 and 3 in one set and Quarters 1 and 4 in another. In a later study Logan and Boles (30) found pairing between the second and third intercept terms but also paired the first and fourth quarters. However, despite similarity in the slope of the demand function with respect to beef consumption the predicted values derived from their quarterly equations displayed grouping of quarters two and three and found quarter four higher and quarter one lower.

If, however, the slopes of the quarterly functions are allowed to vary over the year, i.e., in Model III, a different result is reached. The four linear quarterly equations derived are $3(a)_1$, $3(a)_2$, $3(a)_3$ and $3(a)_4$. The intercept seems to be similar for the second and third quarters being intermediate in value between the greater first quarter value and the lesser fourth quarter intercept. Logan and Boles (30) found this also. However, partly due to changing slope of the demand functions with respect to Beef between four equations $3(a)_1$,

$3(a)_2$, $3(a)_3$, and $3(a)_4$, the predicted values[1] of the price of Beef variable resulted in a regrouping which links quarters one and two in the lesser group and quarters three and four in the greater group. When these predicted values, however, are computed using the values of the independent variables at their respective quarterly means the four predicted values came out practically identical.

The test of the four linear quarterly functions $3(a)_1$, $3(a)_2$, $3(a)_3$ and $3(a)_4$ against the linear function with the quarterly shift variables 2(a) yielded an estimate F value[2] for 18, 26 degrees of freedom of 0.284 whereas the tabled F values at the f and 1 percent significance levels were 2.02 and 2.715 respectively. Thus the hypothesis that the slopes of the functions are the same for all quarters is not rejected even at the 1 percent level. The same testing procedure applied to the logarithmic equations of Model III, $3(b)_1$, $3(b)_2$, $3(b)_3$, and $3(b)_4$ against Model II equation 2(b) yields an estimated F value for the same degrees of freedom as for the linear case of 0.3019. Thus both model forms (i.e., linear and logarithmic) reject the null hypothesis of no quarterly intercept changes and they accept the hypothesis of no quarterly slope changes within the year. Thus Model II is indicated as being most representative of the true demand function for beef underlying the data. Additional information is

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[1]These values are calculated from equations $3(a)_1$, $3(a)_2$, $3(a)_3$ and $3(a)_4$ using the values of the independent variables at their overall arithmetic means.

[2]Explained in sub-section 4.2.3 (Page 40) of the previous chapter and in Equation [3.2.19] (Page 22) of Chapter II.

available from its R^2 values of 0.7604 and 0.6652 for equations 2(a) and 2(b) respectively. Also the F values[1] of 15.515 and 8.713 for the overall significance of the co-efficients of equations 2(a) and 2(b) respectively compared to the tabled F values for 9.44 degrees of freedom of 2.10 and 2.84 at the 5 and 1 percent levels respectively indicate significance at both levels. When the residual sum of squares of the linear equation 2(a) of Model II is compared with the same statistic[2] for the logarithmic function 2(b), equation 2(a) is found to be a superior fit to the data by having a lower sum of squared residuals. 183.20 for 2(a) compared to 249.04 for 2(b). Equation 2(a) has a significantly strong positive time trend as indicated by the co-efficient of the time variable (0.4030) which is significant at both levels of significance. However, the effect of the income variable seems to be non-significant in determining beef prices as indicated by its low co-efficient value (0.0158) compared to its standard error (0.009).

When the tests of hypotheses are performed on the equations using the actual income variable the same results are obtained. These results are also supported by repeating both regressions (i.e., using income and deviations of income from trends) for the second set of consumption data (i.e., total civilian consumption). Similarly, all four regressions (i.e., two sets of consumption data and two versions of "income" variables) select the linear version of Model II as the most suitable model.

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[1] Described on Page 22 of Chapter III and set out on Page 40 of the preceding chapter.

[2] Calculated as explained in section 4.2.2 of the previous chapter.

To test for serial correlation of the residuals all equations fitted had the Hart-Von Neumann statistic computed and tested for significance at the 5 and 1 percent levels of significance.[1] In Table 5.3.1 all the equations of Models I and II have residuals which could not be accepted as random as all the values of the Hart-Von Neumann statistic for these equations were less than even the 1 percent level of significance (i.e., approximately 1.40). The value for the equation 2(a) is 1.0037. All the values of the Hart-Von Neumann statistic for the Model III equations fell under the 95 percent acceptance region and so the assumption of random residuals for these equations are accepted at both the 1 and 5 percent levels. The approximate critical regions for the latter two levels are 1.00 and 1.30 respectively for the Model III equations. The presence of autocorrelation does not affect the unbiased properties of the estimates but the usual tests of significance of those estimates are rendered invalid. Thus in the earlier part of the discussion was placed on the actual estimated co-efficients rather than on their levels of significance.

5.3.2. Pork Table 5.3.2 shows the same information for pork as Table 5.3.1 gave for beef in section 5.3.1. Table 5.3.2 gives the co-efficients, their standard errors, levels of significance and various statistics indicating the goodness of fit of the different equations (i.e., R^2, Sum of Squared Residusls, and F-test). The Hart-Von Neumann statistic is used to test for autocorrelation in the

[1]This test is explained on Page 25 of Chapter III and on Page 40 of Chapter VI.

residuals of the different equations.

The annual Model I, linear and logarithmic form equations are shown in Table 5.3.2 by equations 4(a) and 4(b) respectively. Equation 4(a) has negative co-efficients for the Beef, Pork and Broiler consumption variables. However, this latter co-efficient is not significant at the 5 percent level. The logarithmic equation 4(b) however, reverses the signs of the Mutton and Lamb and Broiler co-efficients, changing the Broiler consumption variable from a complementary relationship with Pork (positive sign) to a more expected competitive relationship (negative sign). The co-efficients of the equations permitting quarterly intercept change are shown by equations 5 (a and b) in Table 5.3.2. The quarterly dummy variables of equation 5(a) indicate a significant deviation in intercept of quarters one, two and three from quarter four. Some seasonal pattern, however, is discernable, placing the second quarter at the bottom, and quarter three next followed by quarter one. On top is quarter four with the largest intercept value of 140.78 given by the constant term of equation 5(a). These findings are supported by those of Logan and Boles (30, p. 1056).

The intercept terms of the four quarterly (Model III) equations, however, reverse the grouping pattern evidenced by the Model II equations 5(a) by placing the intercept term of quarter four function at bottom in intercept in an increasing size scale; next Quarter 1; thirdly Quarter 3 and places Quarter 2 on top. The slope co-efficients with respect to pork of the four quarterly demand functions $(6(a)_1$, $6(a)_2$,

$6(a)_3$, and $6(a)_4$) groups quarters three and four together and also quarters one and two. However, when the quarterly prices are predicted using the values of the variables at their overall means, the grouping is changed. These predicted values for the first, second, third and fourth quarter prices are given by 57.98, 53.43, 56.02 and 64.93 respectively where week groupings exist between quarters one and two.

When the co-efficients of the four linear Model III equations ($6(a)_1$, $6(a)_2$, $6(a)_3$, and $6(a)_4$) are tested against the function with the quarterly shifters 5(a), there is no significant difference indicating that the slopes do not change significantly.

As with Beef, it can be concluded that the quarterly demand function for Pork does differ from the yearly equation (4(a). The test of the co-efficients of the equation with quarterly shift terms 5(a) against the yearly equation 4(a) yielded a test statistic of 16.842. The tabled F values for 3.44 degrees of freedom are 2.82 and 4.26 for the 5 and 1 percent levels respectively. Thus the null hypothesis of no quarterly intercept changes is rejected. This indicates that Model II is again the most appropriate model of the three. The logarithmic equations also accept the hypothesis of no quarterly slope changes and reject the hypothesis of no quarterly intercept changes. Thus, as for Beef, the logarithmic forms of the models agree with their respective linear counterparts in indicating Model II to be the best model. However, the Beef and Pork results differ in the choice between model forms. In the case of Pork the sum of squared residuals of equation 5(b) (187.98) is considerably less than the corresponding value for equation 5(a) is 280.82. This indicates that the data for Pork displays some non-linearity. However, this study only caters for intercept and slope changes under the assumption of linearity. Thus perhaps a third criterion should be added to account for quarterly "curviture" changes for non-linear functions.

Looking more closely at the co-efficients of the "top" equation for pork (i.e., equation 5(b)) it is seen that the co-efficients of all the variables used are significant at the five percent level and all of those except the co-efficient of the Mutton and Lamb consumption variable are significant at the one percent level also. However, the intercept term is non-significant. This state of affairs indicated a strong income effect and a significant time trend in the price of pork.

The Hart-Von Neumann statistic indicates autocorrelation for all the Model I and Model II equations (4(a), 4(b), 5(a), and 5(b)) by rejecting the hypothesis of randomness in the errors of these equations at the 1 percent level of significance. However, this hypothesis was accepted for all the Model III equations ($6(a)_1$, $6(a)_2$, $6(a)_3$, and $6(a)_4$). This result is the same as for the beef set of regressions.

When the straight income and total consumption variables are used (i.e., in the case of the other three sets of regressions) the tests of hypotheses and choice of model form yields the same basic results.

Table 5.3.2. Estimated Co-efficients for Pork Reduced Form Equations.

		Regression Co-efficients and Their Standard Errors[a]			
Dependent Variables	R^2	Constant Term	D_1	D_2	D_3
Model I					
4(a) P_P	.6644	131.24**			
		16.40			
4(b) P_P	.6725	1.2588			
		1.492			
Model II					
5(a) P_P	.8438	140.78**	-6.4065*	-10.2804**	-7.775**
		13.10	1.180	1.604	1.894
5(b) P_P	.8954	- .2192	- .449**	- .0786**	- .0625**
		.911	.007	.008	.008
Model III					
$6(a)_1$ P_{P1}	.9522	146.43**			
		21.61			
$6(b)_1$ P_{P1}	.9603	- 1.6623			
		1.696			
$6(a)_2$ P_{P2}	.8954	165.10**			
		26.73			
$6(b)_2$ P_{P2}	.9235	1.0757			
		2.393			
$6(a)_3$ P_{P3}	.8220	152.51*			
		56.62			
$6(b)_3$ P_{P3}	.8683	.9063			
		2.431			
$6(a)_4$ P_{P4}	.8924	83.98*			
		26.44			
$6(b)_4$ P_{P4}	.9539	- .0671			
		1.424			

[a]Standard errors are shown directly beneath the co-efficients.
** and * mean significant at the 1 and 5 percent levels of significance respectively.

[b]Residual Sum of Squares are given for all the linear equations and selected logarithmic equations where they are calculated as explained on Page 37.

Table 5.3.2. (Continued)

Dependent Variables	Beef	Pork	Mutton and Lambs	Broilers	Income Deviations
	Commercial Consumption				
Model I					
4(a) P_P	- .4073	-3.9124**	1.1144	-2.2218*	.0181
	.683	.517	5.834	1.026	.015
4(b) P_P	- .0057	- .7341**	- .0196	.0030	.4300
	.186	.141	.109	.099	.480
Model II					
5(a) P_P	- .6845	-5.2492**	10.7084*	.8563	.0343
	.597	.417	4.640	1.066	.012
5(b) P_P	- .3021*	-1.1843**	.1810*	.2213**	1.1314**
	.115	.096	.073	.065	.299
Model III					
$6(a)_1$ P_{P1}	-1.2727	-5.9248**	17.5238*	.7553	.0626*
	.914	.641	6.473	2.513	.020
$6(b)_1$ P_{P1}	- .2872	-1.4559**	.3095*	.0876	1.6533*
	.203	.171	.114	.127	.557
$6(a)_2$ P_{P2}	-1.0700	-7.3511**	11.3501	.6024	.0150
	1.290	1.232	15.976	2.733	.030
$6(b)_2$ P_{P2}	- .3469	-1.5679**	- .1815	.3248	.8339
	.245	.316	.217	.240	.754
$6(a)_3$ P_{P3}	- .4073	-6.1477**	.4940	.7349	.0187
	2.183	1.511	14.082	3.147	.031
$6(b)_3$ P_{P3}	- .1820	-1.2344**	.0382	.2767	.7310
	.339	.324	.208	.217	.773
$6(a)_4$ P_{P4}	.2827	-3.4810**	14.0905	3.8609	.0278
	1.135	.582	8.247	2.362	.021
$6(b)_4$ P_{P4}	- .2725	- .7058**	.1419	.5037**	.8628
	.181	.127	.118	.131	.483

Table 5.3.2. (Continued)

Dependent Variables	Time	Sum of Squared Residuals[b]	F-Ratio	Hart - Von Neumann
Model I				
4(a) P_P	.1980 .123	603.30	15.511**	.9567**
4(b) P_P	- .0306 .028		16.085**	.9468**
Model II				
5(a) P_P	- .0193 .240	280.82	26.412**	1.1081**
5(b) P_P	- .0519** .019	187.98	41.831**	1.2012**
Model III				
$6(a)_1$ P_{P1}	.3650 1.090	26.65	19.917**	1.9940
$6(b)_1$ P_{P1}	.0004 .046		24.168**	1.9106
$6(a)_2$ P_{P2}	.5121 1.483	47.12	8.557**	2.4413
$6(b)_2$ P_{P2}	- .0628 .094		12.065**	2.4371
$6(a)_3$ P_{P3}	- .2661 2.018	74.44	5.387*	1.5476
$6(b)_3$ P_{P3}	- .1065 .087		7.691**	2.0635
$6(a)_4$ P_{P4}	-1.5769 1.157	27.74	9.676**	1.4488
$6(b)_4$ P_{P4}	- .1889** .048		24.136**	2.2904

5.3.3. Mutton and Lamb The equations for Mutton and Lamb prices are shown in Table 5.3.3. The negative sign of the beef and pork consumption co-efficients in the single equation 7(a) indicate that these meats serve as substitutes for lamb. However, Tables 5.3.1 and 5.3.2 do not show the inverse relationship. Some quarterly variation is evidenced by equation 5(a) where the intercept term seems to increase above 135.92 (the fourth quarter intercept value) in quarter two and three and to decline below it in the first quarter.[1] The Model III intercepts indicate the same grouping between the second and third quarters at a value intermediate between a high first quarter intercept and a low fourth quarter value. Using the values of the independent variables at their overall arithmetic means to predict the quarterly prices using equations $9(a)_1$, $9(a)_2$, $9(a)_3$, and $9(a)_4$ results in the predicted values of 66.45, 67.83, 70.38 and 71.13 for quarters one through four respectively. This grouping appears to be related to the grouping displayed by the Mutton and Lamb consumption variable co-efficients in the quarterly equations.

Testing the hypothesis of absence of quarterly slope variation with quarterly intercept change yields F values of 0.556 and 0.6209 for the linear and logarithmic functions respectively. When compared with the tabled F values for 18, 26 degrees of freedom of 2.02 and 2.715 for the one and five percent levels of significance respectively the hypothesis is accepted at both levels of significance. In this case Logan and Boles (30, p. 1058) found that the slopes do vary by quarter on average.

[1] Logan and Boles (30, p. 1058) found that any significant shift from the yearly pattern in lamb prices comes in the first and third quarters, with prices being lower in the first period and higher in the third.

Table 5.3.3. Estimated Co-efficients for Mutton and Lamb Reduced Form Equations.

		Regression Co-efficients and Their Standard Errors[a]			
Dependent Variables	R^2	Constant Term[c]	D_1	D_2	D_3
Model I					
7(a) P_P	.6815	124.98** 11.20			
7(b) P_P	.6373	.1839 .969			
Model II					
8(a) P_P	.7044	135.92** 12.63	- .8833 1.139	.4401 1.548	2.0292 1.828
8(b) P_P	.6487	.0311 1.031	- .0052 .008	- .0108 .009	- .0093 .009
Model III					
$9(a)_1$ P_{P1}	.8183	149.09** 25.81			
$9(b)_1$ P_{P1}	.6872	1.4836 2.549			
$9(a)_2$ P_{P2}	.7970	135.30** 24.43			
$9(b)_2$ P_{P2}	.7899	- .1957 2.297			
$9(a)_3$ P_{P3}	.6916	132.73* 51.06			
$9(b)_3$ P_{P3}	.6511	- 2.4722 2.451			
$9(a)_4$ P_{P4}	.7391	67.75 35.81			
$9(b)_4$ P_{P4}	.7783	1.9834 2.322			

[a]Standard errors are shown directly beneath the co-efficients. ** and * mean significant at the 1 and 5 percent levels of significance respectively.

[b]Residual Sum of Squares are given for all the linear equations and selected logarithmic equations where they are calculated as explained on Page 37.

Table 5.3.3. (Continued)

Dependent Variables	Beef	Pork	Mutton and Lambs	Broilers	Income Deviations
	Commercial Consumption				
Model I					
7(a) P_M	-1.0572*	-1.5995**	-13.9905**	- .0597	.0255*
	.467	.353	3.986	.701	.010
7(b) P_M	- .1352	- .2406*	- .2254**	.0881	.6275*
	.121	.092	.071	.064	.312
Model II					
8(a) P_M	-1.6778**	-1.6178**	-11.3349*	- .9617	.0337**
	.576	.402	4.477	1.029	.011
8(b) P_M	- .1721	- .3007**	- .2040*	.1225	.7063
	.130	.109	.083	.073	.339
Model III					
$9(a)_1$ P_{M1}	-2.1544	-2.0629*	- 7.3699	-2.8237	.0268
	1.092	.765	7.730	3.002	.024
$9(b)_1$ P_{M1}	- .1438	- .4680	- .1504	- .0253	.3240
	.305	.258	.171	.190	.838
$9(a)_2$ P_{M2}	- .9854	-2.2439	-17.3538	.3356	.0287
	1.180	1.126	14.604	2.498	.028
$9(b)_2$ P_{M2}	- .1782	- .3096	- .3575	.2320	.7636
	.235	.303	.208	.230	.724
$9(a)_3$ P_{M3}	-2.0808	- .8840	- 9.8575	- .6683	.0543
	1.968	1.362	12.695	2.837	.028
$9(b)_3$ P_{M3}	- .2197	- .1180	- .1144	.0994	1.4252
	.342	.327	.210	.219	.780
$9(a)_4$ P_{M4}	.4913	- .8060	- 9.7870	4.5778	.0002
	1.537	.788	11.167	3.198	.028
$9(b)_4$ P_{M4}	- .0847	- .0006	- .2620	.4364	- .0673
	.295	.207	.193	.214	.788

Table 5.3.3. (Continued)

Dependent Variables	Time	Sum of Squared Residuals[b]	F-Ratio	Hart - Von Neumann
Model I				
7(a) P_M	.2059* .084	281.69	16.761	1.2060**
7(b) P_M	- .0333 .018	308.53	13.763**	1.1166**
Model II				
8(a) P_M	.3705** .135	261.42	11.651**	1.1716**
8(b) P_M	- .0082 .021		9.027**	1.1373**
Model III				
$9(a)_1$ P_{M1}	2.5408 1.302	38.01	4.503*	3.2044
$9(b)_1$ P_{M1}	.0612 .070		2.197	2.3191
$9(a)_2$ P_{M2}	.5514 1.356	39.37	3.926	2.4597
$9(b)_2$ P_{M2}	- .0598 .090		3.759	2.4508
$9(a)_3$ P_{M3}	1.4074 1.819	60.50	2.616	1.8629
$9(b)_3$ P_{M3}	- .0080 .088		2.177	1.9707
$9(a)_4$ P_{M4}	-1.4788 1.566	50.86	3.305	2.0875
$9(b)_4$ P_{M4}	- .1480 .078		4.095*	2.3695

However, when the absence of quarterly intercept variation is hypothesized, the F-test also leads to acceptance for both linear and logarithmic functions. When this new departure [1] is further examined using the other three combinations of variables by introducing the straight income and total consumption variables the same basic results as described above in this sub-section are obtained. This indicates (consistently) that Model I is the best function to describe the quarterly Mutton and Lamb demand function.

The choice of model form (linear or logarithmic) in this case is not so consistent, however, between the different sets of regressions. The change from commercial consumption variables makes no difference in the choice. The inconsistency arises when the straight income variable replaces the income deviations variable. When the income deviations variable is used the linear form is chosen on the basis of low sum of squared residuals. When the straight income variable is used, the reverse conclusion is reached. Thus the results of the former of these two sets of regressions would seem to be the most representative of the true demand function. However, since the former situation is the regression being reported explicitly in these sections the direct and cross price elasticities are based on the linear model while in the next section of this chapter the income elasticities are computed using the logarithmic version of Model I for lamb, since this is the superior form when using the straight income variable.

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[1] In the sense of being a contradiction of the results for Beef and Pork and also those of Logan and Boles (30, p. 1058).

The tests of randomness in the residuals resulted in rejection (at the 5 and 1 percent levels of significance) for equations 7(a), 7(b), 8(a) and 8(b) and in acceptance for equations $9(a)_1$, $9(b)_1$, $9(a)_2$, $9(b)_2$, $9(a)_3$, $9(b)_3$, $9(a)_4$ and $9(b)_4$.

5.3.4. Broilers   Table 5.3.4 gives the results of the set of regressions involving commercial consumption and income deviations as independent variables together with the time and dummy variables. Price of broilers is in the independent position. All the variables in the annual linear equation 10(a) are significant at the five and one percent levels except beef consumption which is not significant and mutton and lamb which is significant at the 5 percent level. The signs of the slope co-efficients with respect to the consumption of pork, mutton and lamb and broilers themselves come out negative for pork and broilers but positive for mutton and lamb. This indicates that broilers and mutton and lamb are weakly complementary while broilers and pork are strongly competitive. However, beef and broilers seem to be neither competitive nor complementary in demand. Comparison of these results with those of sub-section 5.3.1, 5.3.2 and 5.3.3 yields some contradictions. In equation 1(a) of Table 5.3.1 the "beef-broiler" co-efficient was positive and significant at the five percent level of significance only. Equation 4(a) of Table 5.3.2 shows a relationship similar to that of equation 10(a) in Table 5.3.4. The co-efficient relating mutton and lamb price with broiler consumption indicated weak competitiveness. The next section, however, can offer more accurate indications of

Table 5.3.4. Estimated Co-efficients for Broilers Reduced Form Equations.

Regression Co-efficients and Their Standard Errors[a]					
Dependent Variables	R^2	Constant Term[c]	D_1	D_2	D_3
Model I					
10(a) P_C	.9380	57.97**			
		9.78			
10(b) P_C	.9296	- 2.0816			
		1.286			
Model II					
11(a) P_C	.9490	66.70**	.7177	3.5761**	4.2994**
		10.39	.936	1.272	1.503
11(b) P_C	.9565	- 2.0104	.0160	.0395*	.0502**
		1.093	.009	.010	.010
Model III					
$12(a)_1$ P_{C1}	.9779	84.98**			
		16.27			
$12(b)_1$ P_{C1}	.9857	- .4240			
		1.508			
$12(a)_2$ P_{C2}	.9642	97.31**			
		21.17			
$12(b)_2$ P_{C2}	.9765	- 1.8106			
		2.396			
$12(a)_3$ P_{C3}	.9725	26.54			
		36.05			
$12(b)_3$ P_{C3}	.9559	- 2.9789			
		3.093			
$12(a)_4$ P_{C4}	.9445	12.45			
		33.66			
$12(b)_4$ P_{C4}	.9645	- .9823			
		2.935			

[a]Standard errors are shown directly beneath the co-efficients. ** and * mean significant at the 1 and 5 percent levels of significance respectively.

[b]Residual Sum of Squares are given for all the linear equations and selected logrithmic equations where they are calculated as explained on Page 37.

Table 5.3.4. (Continued)

	Commercial Consumption				
Dependent Variables	Beef	Pork	Mutton and Lambs	Broilers	Income Deviations
Model I					
10(a) P_C	.7811	-1.4251**	8.7062*	-1.9261**	.0313**
	.408	.308	3.481	.612	.009
10(b) P_C	- .4674**	- .4435**	.1315	- .2100*	1.5455**
	.160	.122	.094	.085	.414
Model II					
11(a) P_C	.2101	-1.0706**	9.0830*	-3.8261**	.0356**
	.474	.331	3.680	.846	.009
11(b) P_C	- .3983**	- .2037	.0909	- .3807**	1.4240**
	.138	.116	.088	.078	.359
Model III					
$12(a)_1$ P_{C1}	- .1140	-1.2079*	5.5122	-5.6300*	.0186
	.688	.482	4.874	1.892	.015
$12(b)_1$ P_{C1}	- .3196	- .2744	.0957	- .3744*	.9376
	.180	.152	.101	.113	.496
$12(a)_2$ P_{C2}	-1.2824	-1.5399	23.7965	-6.7985*	.0526
	1.022	.976	12.653	2.164	.024
$12(b)_2$ P_{C2}	.4701	- .6264	- .3342	- .7958*	1.6062
	.245	.316	.217	.240	.755
$12(a)_3$ P_{C3}	2.0490	- .6639	8.0432	-1.7293	.0320
	1.390	.962	8.966	2.003	.019
$12(b)_3$ P_{C3}	- .5051	- .0853	.0287	- .4036	1.7415
	.431	.412	.264	.277	.984
$12(a)_4$ P_{C4}	1.8282	- .6820	17.9351	- .0282	.0294
	1.445	.741	10.497	3.006	.027
$12(b)_4$ P_{C4}	- .1779	.1766	.0200	- .0240	.8480
	.373	.262	.244	.270	.996

Table 5.3.4. (Continued)

Dependent Variables	Time	Sum of Squared Residuals[b]	F-Ratio	Hart - Von Neumann
Model I				
10(a) P_C	- .3496** .074	214.79	118.58 **	.8300**
10(b) P_C	- .0594* .024	247.87	103.386**	1.0609**
Model II				
11(a) P_C	- .1077 .111	176.66	91.042**	.7482**
11(b) P_C	- .0210 .022	134.70	107.419**	1.0447**
Model III				
$12(a)_1$ P_{C1}	.2881 .821	15.11	44.228**	2.8560
$12(b)_1$ P_{C1}	- .0276 .041		69.011**	3.3448
$12(a)_2$ P_{C2}	1.5870 1.174	29.56	26.959**	3.3762
$12(b)_2$ P_{C2}	.1517 .094		41.606**	3.2461
$12(a)_3$ P_{C3}	-2.2633 1.285	30.17	41.287**	3.2891
$12(b)_3$ P_{C3}	- .0203 .111		25.310**	3.2815
$12(a)_4$ P_{C4}	-2.5075 1.472	44.94	19.836**	2.6063
$12(b)_4$ P_{C4}	- .1959 .098		31.730**	3.2937

complementarity and competitiveness than can this section which merely has unweighted co-efficients to deal with.

Grouping of quarterly co-efficients of the intercept variables of equation 11(a) yields linking of quarters two and three and quarters one and four in intercept value. The Model III quarterly equations ($12(a)_1$ to $12(a)_4$) have intercept terms which regroup the pairs indicated by equation 2(a). Model III intercepts link quarter one with two and quarter three with quarter four. Logan and Boles (30, p. 1057) found no obvious grouping of the quarterly intercepts into six month periods. When the Model III linear equations ($12(a)_1$ to $12(a)_4$) are used to predict quarterly prices using the values of the independent variables at their overall means predicted quarterly broiler prices for quarters one through four are as follows: 40.74; 45.84; 43.52; 43.22. These quarterly prices support the grouping of quarters three and four as found in the intercept terms of equations $12(a)_1$ through $12(a)_4$. However, grouping of quarter one and two can not be sustained as quarter one value is lower and the quarter four value higher than the paired quarter values. When the co-efficients of the Model I equations (10(a) and 10(b)) are tested against the Model II equations (11(a) and 11(b)) respectively with the null hypothesis of no quarterly variations in the intercept of the broiler demand function the conclusion is to reject the null hypothesis in both linear and logarithmic cases. However, when the hypothesis of no quarterly slope variation is tested by testing the linear and logarithmic Model III equations ($12(a)_1$ and $12(b)_1$ through $12(a)_4$ and $12(b)_4$)

against their respective equations of Model II (11(a) and 11(b)) the hypothesis is accepted at both the five and one percent levels. These results indicate that Model II equations (11(a) and 11(b)) are the most suitable to describe the quarterly broiler retail demand function. The decision of which model form (i.e., 11(a) or 11(b)) is superior rests on their respective residual sums of squares which are 176.66 and 136.70 for the equations 11(a) and 11(b) respectively. This indicates that the logarithmic form given by equation 11(b) in Table 5.3.4 is the best equation to use for broiler demand function among those discussed in this study.

However, some lack of unanimity exists when the other sets of regressions are discussed. When the total consumption variables are substituted for the commercial consumption variables without changing from the income deviations variable, the linear equations accept the null hypothesis of no quarterly intercept changes. This indicates that Model I is the most suitable linear equation. However, changing the consumption variables does not change the inferences of the logarithmic equations, i.e., they indicate the superiority of the Model II equations. When the income deviations variable is used, the conclusion of the linear forms is changed while those of the logarithmic forms remain unchanged. The linear inference now is the that Model II is the best model. The unique equation of superior usefulness seems to be equation 11(b) of Table 5.3.4 which has the logarithmic form of Model II fitted to the variables of Table 5.3.4. However, since the calculation of income elasticities requires the results of fitting an equation using the straight income variable, the linear form of Model II is used. The effects of changing to the alternative consumption variables is interesting here since for broilers both sets are identical and the effect on the choice of the best model is marked. This effect is due to changing the other consumption variables and demonstrates the interdependence between the different meats in demand functions.

The Hart-Von Neumann statistic is applied to all the equations and the results indicate autocorrelation in the yearly equations of Models I and II and lack of it in the quarterly equations of Model III.

5.4. Direct and Cross Price Flexibilities and Elasticities

Having tested the hypotheses set out in Chapter II and examined the regressions performed with special emphasis on the regressions using income deviations and commercial consumption variables, the examination of selected functions remains. On the basis of the tests of hypotheses in section 5.3 equations are selected to estimate elasticities and flexibilities. Table 5.4.1 gives these results togather with an indication of the selected equations used to derive the results. The direct price elasticities and flexibilities are given on top left of the bottom right diagonal of the respective matrices. These matrices are calculated as explained in section 4.5 of the previous chapter. These elasticities and flexibilities are based on the overall arithmetic means of the variables which are given in Table 5.4.2.

Table 5.4.1. Price flexibilities and elasticities using selected models.

			Beef	Pork	Mutton & Lamb	Broilers
(f_{ij}) matrix: flexibilities and cross flexibilities						
Model II	Linear	Beef	-1.0947	- .1100	.0751	.1067
Model II	Logs	Pork	- .3021	-1.1843	.1810	.2213
Model I	Linear	Mutton & Lamb	- .3327	- .3435	- .2244	- .0050
Model II	Logs	Broilers	- .3933	- .2039	.0909	- .3807
(e_{ij}) matrix: elasticities and cross elasticities						
Model II	Linear	Beef	- .8857	.1908	- .2836	- .1512
Model II	Logs	Pork	.5427	- .7553	- .4789	- .1468
Model I	Linear	Mutton & Lamb	.8552	.6820	-3.2262	.3211
Model II	Logs	Broilers	.9827	.2759	- .1556	-1.7725

Table 5.4.2. Overall arithmetic means of the variables used to calculate flexibilities and elasticities variables.

Variables			
Commercial per caput consumption of	Beef (lbs)		21.5759
	Pork (lbs)		14.7222
	Mutton & Lamb (lbs)		1.1000
	Broilers (lbs)		5.7111
Retail price per pound		Beef (cents)	75.2389
		Pork (cents)	58.8352
		Mutton & Lamb (cents)	68.5556
		Broilers (cents)	42.8069

The direct price elasticities for beef and pork are fairly similar and fall into the range found by many previous investigators.[1] The direct price elasticities for mutton and lamb and broilers however appear somewhat greater than previously found by Brandow (5) but quite similar to the results of Logan and Boles (30).[2] The cross elasticities suggest that beef and pork are competing with each other as the cross price elasticities consistently differ in sign from the direct price elasticities. The cross-elasticities between beef and pork (from the beef forecasting equation) and between pork and beef (from the pork reduced form equations) are 0.1908 and 0.5427 respectively. Though these numbers differ in size, they are alike in sign. This is the only example in the matrix (e_{ij}) where such agreement occurs. All the other off diagonal elements contradict in sign their respective conjugate[3] terms. One example of this is offered by the cross-elasticities. One value is -0.1512 whereas its conjugate value is 0.9827. The former value indicates mild complementarity between beef and broilers while the latter value indicates extreme competitiveness.

Table 5.4.3 shows the quarterly variation in the direct price flexibilities and elasticities found for the linear models. Beef shows extremely

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[1]Working (70) found that the short run elasticity of demand for pork was to be -0.75 whereas in the long run it was about -1.25. The average of these should compare with the findings of the present study (i.e., -1.00). Tomek and Cochrane (45) found the same figure to be about -0.77 for pork and -0.8 for beef.

[2]Brandow (5) found the elasticity of demand for chickens to be about -0.74 and for sheep and lambs to be -1.78. Logan and Boles (30, p. 1059) found the even price elasticities for beef, pork, mutton and lamb and broilers to be -0.651, -0.941, -3.179, and -2.758 respectively.

[3]This term is borrowed from Physics and is used here to distinguish between the two cross-elasticities describing the same phenomenon but derived differently.

Table 5.4.3. Price flexibilities and elasticities by quarters from linear models using the income deviations and commercial consumption variables.

	Beef	Pork	Mutton & Lamb	Broilers
Price flexibilities				
Model II First Quarter	-1.0671	-1.3580	- .2437	- .4650
Model II Second Quarter	-1.0966	-1.2705	- .2182	- .5502
Model I Third Quarter	-1.271	-1.1887	- .2139	- .5461
Model II Fourth Quarter	-1.0862	-1.4443	- .2238	- .4788
Elasticities				
Model II First Quarter	- .9086	- .6212	-2.9719	-1.9944
Model II Second Quarter	- .8842	- .6640	-3.3197	-1.6855
Model I Third Quarter	- .8602	- .7097	-3.3863	-1.9370
Model II Fourth Quarter	- .8926	- .5841	-3.2361	-1.9370

little quarterly variation. The quarterly price elasticities for pork seem to rise consistently starting in the fourth quarter which is lowest and growing steadily through the first, second and third quarters. The mutton and lamb elasticities are jointly highest in the second and third quarters, lowest in quarter one and intermediate in quarter four. The broiler quarterly elasticities display identically between quarters three and four at a level intermediate between a higher first quarter elasticity and a lower second quarter value.

These elasticities and flexibilities were calculated by the method shown in section 5.5 of the previous chapter using the values of the variables at their respective quarterly means. These means are calculated by dividing the overall data into four parts by individual quarter and then taking the arithmetic means for the various variables for each quarter. The means used in this study are shown in Table 5.4.4.

The income elasticities of demand are shown in Table 5.4.5. These are computed from the selected best models where the straight income variable is used. The same choice of model for the four meats result (i.e., Model II for beef, pork and broilers and Model I for mutton and lamb). However, the linear version of Model II was used for beef and broilers while the logarithmic version of Model II was preferred for pork. Finally the mutton and lamb equation was in logarithmic form. These income elasticities are contrary to expectations because they are all negative. Negative elasticities normally imply inferior goods, i.e., when income increases the quantity demand decreases. But these meats are usually not in this category. This casts a doubt on their method of estimation as used here.

Some fundamental and interesting relationships between the rows and columns of elasticity-cross-elasticity matrices; income elasticity vectors and budget proportions are explained by Houck (23). Due to absence of information on budget proportions these relationships have not been tested out in this study.

Table 5.4.4. Quarterly arithmetic means of variables used in calculation of quarterly flexibilities and elasticities.

		Quarters			
		1	2	3	4
Beef quantities	=	21.04	21.53	22.24	21.45
Pork quantities	=	14.96	14.08	13.88	15.94
Mutton & Lamb quantities	=	1.17	1.08	1.07	1.08
Broilers quantities	=	5.26	6.17	6.25	5.16
Beef prices	=	75.26	74.95	75.34	75.39
Pork prices	=	57.83	58.16	61.29	57.94
Mutton & Lamb prices	=	67.12	69.55	70.09	67.29
Broilers prices	=	43.29	42.9	43.79	41.29

Table 5.4.5. Income elasticities of demand for beef, pork, mutton and lamb and broilers.

Meats	Income elasticity
Beef	-0.5890
Pork	-0.4957
Mutton & Lamb	-0.9832
Broilers	-0.8330

5.5. Effect of Intercorrelation

The major intercorrelation problems involved in the analysis are summarized in Table 5.5.1 together with an insight into the effects of changing from the straight variables to the deviations of income from trend variable. Table 5.5.1 shows that by changing from the straight trend variable to the deviations of income from trend variable the marked intercorrelation between the income variable and consumption of beef and broilers and time variables is considerably reduced. There remains then only the intercorrelation between the consumption variables and the time trend variable.

In this study each of the eight sets of multiple regressions involves the estimation of 180 parameters. The effects of changing from the straight income variable to the deviations from trend version of this variable when the commercial consumption variables were used caused a significant change[1] in 35 out of the 180 estimates for the logarithmic functions and a significant change in 24 out of the 180 linear estimates. It is interesting to note that out of the 35 logarithmic changes 9 were changes in the co-efficients of the income variable and 9 were changes in the co-efficients of the commercial consumption of beef variable while only 3 and 2 were the number of significant changes in time and commercial consumption variables respectively. Of the 24

[1]This change was denoted by observing the change in the significance of the estimated parameters, i.e., whether the estimated co-efficient changed from being significant at the 5 or 1 percent levels or from not being significant.

Table 5.5.1. Correlation matrix between time, income and commercial consumption for logarithmic variables and linear variables.

	Logarithmic variables			Linear variables		
Variables	Income	Time[a]	Income deviations + mean of the income variable[b]	Income	Time	Income deviations
Straight income	1.000		0.3021	1.000		0.3373
Time trend	0.8433	1.000	-0.1450	0.9405	1.000	0.0023
Commercial consumption of beef	0.9339	0.7467	0.2788	0.9388	0.8915	0.3063
Commercial consumption of broilers	0.8219	0.9081	-0.1464	0.8375	0.9180	-0.0796

[a]The correlation for the time variable is an average of the correlation of the two time variables (one annual and the other quarterly).

[b]Due to the negative sign of some of the elements of the income deviations variable a constant is added to make all the elements positive and hence amenable to logarithmic analysis. The constant used is the mean of the income variable (1928.2904).

changes in the linear estimates 14 were changes in the constant term in the equation and the remaining 8 were in the co-efficients of the time variables. Thus it would seem that the degree of intercorrelation between two independent variables in a multiple regression is not a good indication of what co-efficients are biased by the presence of that intercorrelation.

CHAPTER VI. SUMMARY AND CONCLUSIONS

In this study the retail demand functions of four meats beef, pork, mutton and lamb and broilers are studied for the period 1953 (third quarter) to 1966 (fourth quarter) to determine the nature of quarterly fluctuations in those demand functions. The reduced forms of the functions were estimated using least squares under three different sets of assumptions. The first set allowed no quarterly fluctuation in the demand functions; the second allowed ~~no~~ seasonal intercept changes and the third allowed both intercept and slope to vary quarterly during the year. Using the same sets of independent variables for each meat forecasting equation (i.e., per capita consumption of beef, pork, mutton and lamb and broilers, per capita disposable income and time trend) the three models were fitted both linearly and logarithmically and for two different sets of consumption variables (one for total and one for commercial consumption). To avoid intercorrelation problems between income and other independent variables the four regressions are repeated using a deviations from trend income variable. Within the resulting eight sets of regressions tests of homogeneity between the three models were performed to test their underlying assumptions. In all cases the hypothesis that the slope of the demand function are constant over the year was not rejected. In the cases of beef and pork the hypothesis that the intercept of the demand function was identical by quarters within the year was rejected. In the cases of mutton and lamb this hypothesis was accepted meaning that an annual demand function is adequate for this meat. For broilers, the logarithmic functions lead to rejection of this hypothesis as do the linear equations for the commercial consumption set of variables. However, for the linearly fitted set of equations with total consumption variables the hypothesis was accepted.

When selected logarithmic equations are compared to fit to the data with their selected linear counterparts the linear models came out on top for beef while the pork data was better fitted by the logarithmic versions. For the commercial consumption and deviations from trend variables the linear equations were superior in the case of mutton and lamb while the broiler equations allowing quarterly intercept changes were better fitted by the logarithmic form of model.

Using the models of superior fit all the meat prices except broilers showed significant time trends though it was weak for mutton and lamb. Beef has a positive time trend while pork has a negative trend. Using the same equations the reduced direct price elasticities were as follows: Beef, -0.8857; Pork, -0.7553, Mutton and Lamb, -3.2262 and Broilers, -1.7725. Quarterly variations in elasticities reduced from the linear versions of the same selected models did not indicate substantial importance of this form of variation though some was evident. From the models of superior fit using the straight income variable the following income elasticities of demand were calculated: Beef, -0.5890; Pork, -0.9832 and Broilers, -2.8330.

In all the selected equations the hypothesis of random residuals was rejected at the one percent level of probability using the Hart-Von Neumann statistic.

The use of semi-annual data was not supported by the grouping of quarterly co-efficients for the set of regressions using commercial consumption and deviations from trend income variables. Though considerable seasonal variation in the co-efficients is ~~are~~ observed, the pairing of the different quarters was not consistant enough to support grouping of the quarters into larger time units.

CHAPTER VII. SUGGESTIONS FOR FURTHER STUDY

In this study autocorrelation was indicated for all the Models I and II equations. The selected equations for each meat were from these two models. The main consequences of autocorrelation when ordinary least squares are used are set out in Chapter III (Page 24). These consequences must be considered when evaluating the results of this study as set out in Chapter V.

This, however, goes only part of the way toward an answer to the problem. The F-tests used (Page 22) to test the hypotheses in this study are affected by the presence of autocorrelation in the residuals. The derivation of this test assumes randomness in the residuals. Thus the test is invalid.

Further research may determine the cause of the autocorrelation and elucidate its structure. Some methods for doing this are set out by Johnston (24) and Goldberger (14). Transformation of the data and/or method of analysis may reduce or eliminate the problem.

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CHAPTER IX. ACKNOWLEDGEMENTS

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CHAPTER X. APPENDIX

Table 1. Principle series used in analyses.

	A Retail consumer price index (1952-59 = 100)	B Disposable consumer income	C Deflated retail prices per pound (cents)			
			Beef	Pork	Lamb	Broilers
1949 1	83.2	1531.2	77.9	65.9	72.0	65.0
2	83.1	1522.3	81.2	67.0	90.6	69.7
3	82.9	1516.3	85.2	70.2	83.0	68.6
4	82.6	1526.6	85.7	62.6	76.0	66.8
1950 1	82.0	1634.1	83.2	59.9	77.3	61.8
2	82.6	1611.4	89.2	63.8	85.4	67.8
3	84.5	1627.2	94.6	71.7	83.8	70.4
4	86.2	1631.1	92.3	64.0	81.9	63.8
1951 1	89.3	1612.5	97.4	65.2	82.1	64.9
2	90.2	1627.5	97.9	64.7	84.8	65.7
3	90.6	1626.9	97.8	65.9	85.0	64.9
4	91.8	1620.9	96.7	62.6	86.5	61.0
1952 1	91.8	1617.6	96.0	59.2	82.1	63.6
2	92.5	1617.3	94.4	59.8	81.4	59.4
3	93.1	1644.5	92.6	65.0	83.4	63.5
4	93.1	1670.2	91.0	61.1	74.8	64.8
1953 1	92.6	1696.5	76.8	61.1	66.3	62.7
2	93.0	1710.8	71.0	68.2	71.8	60.4
3	93.7	1693.7	74.0	73.1	71.3	60.9
4	93.8	1685.5	73.9	66.3	65.4	59.1
1954 1	93.7	1688.4	72.8	71.6	66.2	56.0
2	93.6	1679.5	72.8	72.5	73.5	55.6
3	93.7	1687.3	72.7	67.6	70.3	55.7
4	93.3	1719.2	74.6	62.0	67.0	51.3
1955 1	93.2	1739.3	74.7	58.7	67.2	56.8
2	93.1	1775.5	72.7	58.9	68.9	60.3
3	93.5	1800.0	71.7	60.4	70.3	58.6
4	93.6	1817.3	70.3	54.1	63.6	51.8
1956 1	93.4	1834.0	66.5	50.5	61.1	51.3
2	94.1	1840.6	66.5	54.8	71.0	49.9
3	95.3	1833.2	71.9	57.7	70.3	49.3
4	96.0	1849.0	73.8	56.0	64.1	45.3
1957 1	96.6	1847.8	68.7	58.6	63.2	47.0
2	97.6	1843.2	71.4	60.7	70.4	47.0
3	98.6	1840.8	74.2	66.1	71.5	47.8
4	99.0	1825.3	73.8	59.6	69.6	42.9

Table 1. (Continued)

	A Retail consumer price index (1952-59 = 100)	B Disposable consumer income	C Deflated retail prices per pound (cents)			
			Beef	Pork	Lamb	Broilers
1958 1	100.0	1803.0	78.8	62.8	73.2	46.2
2	100.7	1797.4	82.2	65.4	71.6	46.5
3	100.9	1827.6	80.6	66.6	73.6	44.4
4	100.9	1846.4	80.3	61.4	72.6	40.4
1959 1	100.8	1866.1	82.3	58.4	67.3	41.7
2	101.2	1889.3	82.4	57.3	70.9	40.3
3	101.8	1870.3	81.1	56.1	71.0	39.9
4	102.3	1875.9	80.3	52.4	64.3	38.6
1960 1	102.3	1885.6	79.4	50.9	66.1	41.1
2	103.0	1886.4	79.7	54.4	68.2	40.7
3	103.2	1883.7	78.1	57.2	65.7	40.4
4	103.8	1862.2	76.7	56.6	65.8	38.4
1961 1	103.9	1869.1	78.6	57.2	64.0	39.4
2	103.9	1892.2	76.1	55.9	61.1	36.3
3	104.4	1908.0	73.7	57.4	61.4	34.1
4	104.6	1936.9	75.4	56.0	62.0	33.5
1962 1	104.8	1947.5	76.9	55.1	64.3	38.7
2	105.2	1959.1	76.5	54.8	65.2	36.8
3	105.7	1956.5	78.5	58.7	67.5	37.1
4	105.9	1965.1	80.8	56.5	66.7	37.0
1963 1	106.1	1984.0	79.6	54.2	66.9	37.1
2	106.3	1993.4	74.4	52.0	67.5	36.5
3	107.1	2001.9	75.1	55.5	67.0	36.0
4	107.4	2023.3	74.5	52.9	65.8	35.9
1964 1	107.7	2058.5	72.0	51.6	66.8	34.8
2	107.9	2105.7	70.4	50.8	66.6	34.6
3	108.3	2125.6	72.5	53.6	69.5	35.3
4	108.7	2140.8	73.0	52.5	69.5	35.1
1965 1	108.9	2161.6	72.2	52.2	69.4	35.2
2	109.7	2176.8	73.4	54.4	72.2	35.6
3	110.1	2233.4	76.5	63.3	75.4	36.5
4	110.7	2260.2	74.9	63.9	72.6	34.8
1966 1	111.5	2275.3	75.9	70.0	76.9	37.5
2	112.7	2271.5	75.9	64.2	77.1	37.6
3	113.7	2285.0	74.1	64.7	76.4	37.0
4	114.6	2302.8	73.1	61.0	75.0	33.7

Table 1. (Continued)

		D Total civilian consumption (lbs per capita)				E Consumption from commercial sources (lbs per capita)			
		Beef	Pork	Lamb	Broilers	Beef	Pork	Lamb	Broilers
1949	1	15.3	14.5	1.1	1.7	16.0	17.6	1.2	1.7
	2	15.2	13.5	0.8	2.0	15.9	15.7	0.8	2.0
	3	16.1	13.2	1.0	1.9	16.7	14.9	1.0	1.9
	4	14.5	16.1	1.1	1.4	15.3	19.5	1.1	1.4
1950	1	14.9	15.4	1.0	2.0	15.7	18.2	1.0	2.0
	2	15.0	14.3	0.9	2.3	15.6	16.3	1.0	2.3
	3	15.7	13.5	1.0	2.2	16.2	15.1	1.0	2.2
	4	15.1	16.4	0.9	2.2	15.9	19.6	0.9	2.2
1951	1	13.9	15.3	0.9	2.1	14.7	18.1	0.9	2.1
	2	12.7	15.1	0.7	2.9	13.3	17.2	0.8	2.9
	3	13.8	15.0	0.8	3.0	14.4	16.4	0.8	3.0
	4	13.0	17.0	0.9	2.4	13.7	20.2	0.9	2.4
1952	1	13.6	16.6	1.0	2.7	14.4	19.3	1.0	2.7
	2	14.1	15.0	0.9	3.5	14.7	16.8	1.0	3.5
	3	15.9	14.9	1.0	3.1	16.5	16.2	1.0	3.1
	4	15.8	17.2	1.1	2.4	16.6	20.1	1.1	2.4
1953	1	17.0	15.5	1.2	2.9	17.9	17.7	1.2	2.9
	2	18.4	13.1	1.0	3.3	19.2	14.7	1.1	3.3
	3	19.7	12.7	1.1	3.4	20.4	13.9	1.2	3.4
	4	19.2	14.7	1.2	2.7	20.1	17.2	1.2	2.7
1954	1	19.1	13.0	1.2	3.4	20.0	15.0	1.2	3.4
	2	19.0	12.2	1.1	3.6	19.8	13.6	1.1	3.6
	3	19.8	12.9	1.1	3.6	20.6	13.9	1.1	3.6
	4	18.8	15.3	1.1	3.1	19.7	17.5	1.1	3.1
1955	1	18.7	15.2	1.2	2.8	19.5	17.2	1.2	2.8
	2	19.5	13.6	1.1	3.7	20.3	15.0	1.2	3.7
	3	20.8	13.9	1.1	4.1	21.6	15.0	1.1	4.1
	4	19.7	17.3	1.1	3.3	20.6	19.6	1.1	3.3
1956	1	20.3	16.8	1.2	3.7	21.3	18.7	1.2	3.7
	2	20.7	14.2	1.0	4.6	21.5	15.6	1.0	4.6
	3	20.6	14.1	1.0	5.0	21.3	15.1	1.1	5.0
	4	20.6	16.1	1.0	4.2	21.3	18.0	1.1	4.2
1957	1	20.9	14.3	1.1	4.2	21.5	15.9	1.2	4.2
	2	20.3	13.4	1.0	5.0	20.8	14.6	1.0	5.0
	3	21.1	13.2	1.0	5.3	21.5	14.0	1.0	5.3
	4	20.1	15.2	1.0	4.6	20.7	17.0	1.0	4.6

Table 1. (Continued)

	D Total civilian consumption (lbs per capita)				E Consumption from commercial sources (lbs per capita)			
	Beef	Pork	Lamb	Broilers	Beef	Pork	Lamb	Broilers
1958 1	18.9	13.5	1.0	4.8	19.6	15.1	1.0	4.8
2	19.3	13.1	1.1	5.7	19.7	14.2	1.1	5.7
3	20.6	13.4	1.0	6.5	21.0	14.3	1.0	6.5
4	19.6	15.3	1.0	5.1	20.2	17.1	1.0	5.1
1959 1	18.6	15.2	1.2	5.3	19.2	16.9	1.2	5.3
2	19.9	14.7	1.1	6.4	20.4	15.9	1.1	6.4
3	20.9	15.3	1.1	6.2	21.4	16.1	1.1	6.2
4	20.0	17.5	1.1	4.9	20.6	19.4	1.1	4.9
1960 1	20.4	16.3	1.2	5.4	21.0	17.5	1.2	5.4
2	20.4	14.8	1.1	6.3	20.9	15.7	1.1	6.3
3	22.0	14.5	1.1	6.9	22.4	15.2	1.1	6.9
4	20.4	15.4	1.1	5.4	20.9	16.9	1.2	5.4
1961 1	20.4	14.7	1.3	6.0	21.0	15.9	1.3	6.0
2	21.8	14.3	1.3	7.5	22.3	15.1	1.4	7.5
3	22.3	13.7	1.2	7.4	22.7	14.2	1.2	7.4
4	21.4	15.8	1.2	5.4	22.0	17.1	1.2	5.4
1962 1	21.5	15.3	1.4	5.9	22.1	16.3	1.5	5.9
2	21.7	14.8	1.2	6.9	22.1	15.6	1.2	6.9
3	22.5	14.1	1.2	7.1	22.9	14.6	1.2	7.1
4	21.4	16.4	1.3	6.1	22.0	17.5	1.3	6.1
1963 1	21.9	15.6	1.3	6.4	22.5	16.5	1.3	6.4
2	23.0	15.2	1.1	7.2	23.5	15.9	1.1	7.2
3	24.1	14.6	1.2	7.6	24.5	15.1	1.3	7.6
4	23.5	17.0	1.2	6.1	24.0	18.0	1.2	6.1
1964 1	23.6	15.9	1.2	6.7	24.1	16.6	1.2	6.7
2	25.3	14.9	1.1	7.4	25.8	15.6	1.0	7.4
3	25.1	14.7	0.9	7.6	25.5	15.2	1.0	7.6
4	24.7	17.0	1.0	6.3	25.3	17.9	1.0	6.3
1965 1	24.1	15.2	0.9	6.6	24.6	15.8	0.9	6.6
2	23.6	14.1	0.9	7.6	24.0	14.8	0.9	7.6
3	25.1	13.4	1.0	8.1	25.5	13.9	1.0	8.1
4	24.9	14.0	0.9	7.1	25.5	14.5	0.9	7.1
1966 1	25.1	13.5	1.0	7.2	25.3	13.5	1.0	7.2
2	25.4	13.7	1.0	8.3	25.6	14.2	1.1	8.3
3	26.8	13.8	1.0	8.7	26.9	14.1	1.0	8.7
4	26.0	16.2	0.9	8.0	26.2	16.2	0.9	8.0

Table 1. (Continued)

	F Total civilian consumption			G Total production (million lbs)		
	Beef	Pork	Mutton & Lamb	Beef	Pork	Lamb
1949 1						
2						
3						
4						
1950 1						
2						
3						
4						
1951 1						
2						
3						
4						
1952 1						
2						
3						
4						
1953 1						
2						
3						
4						
1954 1						
2						
3						
4						
1955 1						
2						
3						
4						
1956 1						
2						
3						
4						
1957 1	3592	2660	194	3654	2875	192
2	3498	2449	172	3432	2284	172
3	3631	2363	174	3615	2191	175
4	3511	2883	170	3510	3132	168

Table 1. (Continued)

		F			G		
		Total civilian consumption			Total production (million lbs)		
		Beef	Pork	Mutton & Lamb	Beef	Pork	Lamb
1958	1	3329	2580	172	3297	2716	172
	2	3376	2428	186	3224	2302	184
	3	3613	2447	168	3424	2311	161
	4	3480	2944	176	3397	3199	171
1959	1	3324	2922	209	3250	3119	202
	2	3549	2771	185	3345	2625	171
	3	3732	2815	190	3475	2622	175
	4	3625	3406	199	3538	3744	190
1960	1	3697	3099	210	3630	3300	193
	2	3699	2775	194	3575	2712	182
	3	3981	2701	205	3817	2463	193
	4	3743	3013	206	3703	3155	200
1961	1	3762	2847	231	3714	3031	215
	2	4016	2709	245	3854	2640	214
	3	4101	2574	224	3884	2442	198
	4	3992	3099	223	3844	3299	205
1962	1	4015	2957	267	3815	3139	215
	2	4043	2840	214	3791	2787	190
	3	4203	2675	228	3871	2491	197
	4	4042	3213	241	3819	3424	207
1963	1	4154	3048	249	3959	3278	199
	2	4352	2947	213	4081	2883	176
	3	4566	2817	226	4161	2695	196
	4	4493	3360	220	4242	3583	199
1964	1	4529	3113	223	4376	3392	189
	2	4844	2930	197	4681	2894	172
	3	4811	2879	183	4610	2638	172
	4	4800	3381	191	4757	3599	182
1965	1	4684	3000	177	4616	3141	166
	2	4581	2816	171	4445	2605	157
	3	4874	2658	188	4761	2507	164
	4	4887	2785	180	4871	2912	164
1966	1	4878	2618	188	4837	2743	159
	2	4950	2751	208	4820	2645	167
	3	5216	2726	192	5031	2621	164
	4	5095	3146	183	5037	3328	160