1973

Quarterly models for forecasting live hog prices

Dyaa K. Abdou
Iowa State University

Quarterly models for forecasting live hog prices

by

Dyaa Kamal Abdou Ahmed Kamal-Abdou

A Thesis Submitted to the

Graduate Faculty in Partial Fulfillment of

The Requirements for the Degree of

MASTER OF SCIENCE

Department: Economics

Major: Agricultural Economics

Signatures have been redacted for privacy

Iowa State University
Ames, Iowa

1973

TABLE OF CONTENTS

I. INTRODUCTION

The seasonal variation in the demand for and supply of meat has an important implication for all agencies involved in the livestock and meat industries. This includes producers as well as those engaged in marketing, processing and distribution activities. Those economic agencies are often faced with the need to make decisions which involve the future. This need for making such a decision does not wait because the agencies are not able to accurately foresee the future. The adequate forecast provides the decision maker with valuable tools, both to simulate the various effects of alternative decisions that may be under his control and to evaluate the economic effects of those beyond his control. For most farm products, because of the generally inelastic demand, small errors in supply estimates may lead to sizeable errors in price estimates. Thus, adequate forecasts help in more informed judgment about possible future developments, thereby reducing the degree of uncertainty involved in making any decision concerning the future.

This study is part of a project at the Iowa State University Agricultural Experiment Station to study and analyze the demand and supply for Iowa's main agricultural products. This phase of the project focuses on the hog market and the nature of supply, demand and price relationships in the market.

In Iowa, the swine industry has a great impact upon both the economy and the society. The hogs produced are considered as an important market for the grain produced on Iowa farms as well as a major market for the labor on those farms. Iowa produces about 25 percent of all hogs in the United

States and marketed about 22.6 million hogs in 1971. Approximately thirty percent of Iowa cash receipts from farm marketings are accounted for by hogs.

This significant impact of the swine industry upon the Iowa economy adds emphasis to the important role of accurate forecasting for all economic agencies in the industry. The main objective of this study is to estimate price-quantity relationships on live hogs in order to generate reasonably accurate forecasts of prices, given reliable estimates of specified relevant variables. To achieve this objective, three specific areas were identified for analysis using quarterly data. The first of these is to study the seasonal differences, if any, in demand and price relationship for hogs at the primary market level. Two major statistical problems are considered, namely, the intercorrelation problem between the explanatory variables and the autocorrelation problem between the successive disturbances resulting from the time series data analysis.

The second area of emphasis is to compare the efficiency of prediction for two types of models. One group of models permitted the effect of changes in general price level to be reflected in the results, with certain variables measured in current (nominal) dollars. In the other models, the effect of price level change was eliminated by using the consumer price index as a deflator for some variables.

The third area was to study the effect, if any, of different levels of supply of pork (i.e., high, medium and low levels of per capita consumption of pork) on the nature of the price-quantity relationship.

Many studies have been done concerning the demand for different kinds of meats, i.e., Fox (9), Stone (33) and Wold (45). All of these studies were constructed using yearly data, thus they did not reflect any fluctuation for prices over any specific period of time within the year. However, some studies concerning the seasonal variation in demand have been done using quarterly data, Buttimer (3), where the study was concerned with determining the nature of the quarterly fluctuations in the retail demand functions of beef, pork, mutton and lamb and broilers. There was no evidence of changes in the slope of the demand between quarters in all cases. However, there was evidence of differences in the intercept level between quarters for the demand for beef and pork. The mutton and lamb demand function was shown to have identical intercepts by quarters within the year. Using the broilers logarithmic function, the hypothesis of identical intercept by quarters was rejected. Ladd (20) showed that the linear seasonal shift model is more appropriate to use than the seasonally adjusted data model. The former permits testing of one hypothesis about seasonal variation in parameters, while the latter does not permit testing any hypothesis about seasonal variation in parameters. Logan and Boles (23) in their study were concerned with the retail demand for beef, pork, broiler and lamb, with major emphasis on analyzing the seasonal variation in prices and consumption of these meats by means of quarterly data. In all cases except lamb, the hypothesis that the slopes of the demand function are constant over the year was not rejected. However, in all cases, the hypothesis that the level of the demand function was identical by quarters within the year was rejected. They also showed that in all cases, the linear demand function exhibited lower sums of squared residuals than the logarithmic functions.

This chapter is followed by the relevant economic and statistical considerations in Chapters II and III respectively. Chapter IV discusses the analytical procedure and hypothesis used to achieve the objectives of the study. Chapters V and VI are devoted to the empirical results and summary, conclusion and suggestions for further study respectively.

II. ECONOMIC CONSIDERATIONS

A. Introduction

This chapter is devoted to a discussion of the economic theoretical considerations relevant to this study. This economic theory, along with the statistical considerations discussed in the next chapter, provide the framework of the study. The relevant theory of demand will be discussed in Section B. Section C is devoted to the elasticity and flexibility aspects. Substitutes and complementary goods, and other considerations are discussed in Sections D and E respectively.

B. Theory of Demand

In the theory of consumer behavior, the consumer is assumed to choose among the alternative available to him in such a way as to get as much satisfaction as possible from consuming commodities given the resources available. He is also assumed to prefer more than less. The cardinal utility theory assumes that utility is cardinally measurable and the difference between those utility numbers could be compared. Moreover, such utility was assumed to be additive and characterized by diminishing marginal utility. However, those assumptions are very restrictive and the results about demand and consumer behavior could be obtained from weaker assumptions.

In the ordinal utility theory, the consumer is assumed to have a way of ranking (ordering) commodities. This preference relationship is complete, transitive, continuous and has a semi-strict convexity which is equivalent to the assumption of quasi-concavity of utility function. The ordinal utility function could be written as:

$$U = f(q_1, q_2, \ldots, q_n) \tag{1}$$

$$U = f_i(q_i)$$

$i = 1, 2, \ldots, n$ (quantities of n commodities)

The utility function is continuous and has first and second order partial derivatives. This function is not unique since in general any single valued increasing function can serve as a utility function. This utility function is defined with reference to consumption during a specified period of time. Now, the indifference curve which represents the locus of combinations from which the consumer derives the same level of satisfaction can be formed with certain properties. The collection of indifference curves that correspond to different levels of satisfaction represent an indifference map. Given the utility function as in (1), we can describe the indifference curve by

$$U(q_1, q_2, \ldots, q_n) = C \tag{2}$$

where C is a constant.

The indifference map is generated by allowing C to take every possible value. Taking the total differential of (1)

$$dU = f_1 dq_1 + f_2 dq_2 + \ldots + f_n dq_n = \sum_{i=1}^{n} f_i dq_i \tag{3}$$

where f_i's are the partial derivatives of U with respect to q_i and $i = 1, 2, \ldots, n$.

Using two goods, q_1, q_2, and by setting the total of differential for those two goods equal to zero, solving for $(-\frac{dq1}{dq_2})$ the slope of the indifference curve

$$-\frac{dq_1}{dq_2} = \text{M.R.S.}_{q_1 \text{ for } q_2} = \frac{\partial U/\partial q_1}{\partial U/\partial q_2}$$

where the M.R.S. = marginal rate of technical substitution. Using this indifference curve analysis we usually assume that consumers don't reach the saturation point, also assuming diminishing marginal rate of substitution. The indifference curves by themselves cannot predict consumer behavior. Other criteria about the prices of the commodities and consumer income must also be considered.

Assuming that during a given period of time the consumer possesses a fixed income Y (Y > 0) which is used to purchase the commodities, given a set of market prices, this income is

$$p_1q_1 + p_2q_2 + \dots + p_nq_n = \sum_{i=1}^{n} p_iq_i = Y \tag{4}$$

The consumer behavior is implicitly defined by the assumption that the consumer maximizes utility, (Equation 1) subject to income constraint (Equation 4). Using the Lagrangian multiplier and by differentiating with respect to Y and q's will yield a system of equations

$$\frac{\partial L}{\partial q_i} = f_i - \lambda p_i = 0 \tag{5}$$

$$\frac{\partial L}{\partial \lambda} = \sum_{i=1}^{n} p_iq_i - Y = 0 \tag{6}$$

From these first order equations, we can see that the marginal rate of substitution (M.R.S.) must equal the price ratio for a maximum

$$\frac{f_i}{f_j} = \frac{p_i}{p_j}$$

This is the necessary condition for maximization. The sufficient condition to define a maximum requires that utility system is convex in the sense that constrained maxima is unique.

The ordinary marshallian demand function can be derived from the analysis of utility maximization. Solving for the unknown parameters in the equations of the first order, the solution of q's are in terms of p_i and Y. Thus the quantity of q_1 that the consumer purchases in the general case depends upon the prices of all the commodities and his income.

$$q_1 = f_i(p_1, p_2, \ldots, p_n, Y),$$

where the proportional increase in the prices and income leave the first order equation unaffected except for a similar decrease in λ. Thus we conclude that the demand function is homogeneous of degree zero in prices; only the relative prices and income are involved. If such proportionate change in prices leaves his behavior unaltered there is an absence of money illusion.

C. Elasticity and Flexibility

Price and income elasticity are important concepts in demand and price analysis. Price elasticity of demand relates a proportional change in quantity to a proportional change in prices. It is a pure number independent of the units in which prices and output are measured. The elasticity of demand could be written as

$$\frac{\partial(\text{Log } q_i)}{\partial(\text{Log } p_j)} = \frac{\partial q_i}{\partial p_j} \frac{p_j}{q_i}$$

when i = j this will be the own-price elasticity of demand and where all the other p's and income are held constant, which is negative. When $i \neq j$ this will be the cross price elasticity of demand.

Let the demand function take the following form

$$p_1 = f_i(q_i, q_2, \ldots, q_n, Y)$$

This will lead to the important piece of information desired in this study. The price flexibility shows the proportional change in prices due to a change in the quantity, which can be written as

$$\frac{\partial(\log p_i)}{\partial(\log q_j)} = \frac{\partial p_i}{\partial q_j} \frac{q_j}{p_i}$$

Again when i = j, this would be the own-price flexibility holding all other q's and Y constant. When $i \neq j$ this would be the cross price flexibility where it relates the proportional change in one price to the proportional change of the other quantity. This may be positive or negative. Using the last demand function in double logarithm form, it will represent constant flexibility which is given by the first partial derivatives with respect to the variable concerned.

The income flexibility measures the percentage change in prices associated with one percent change in income

$$\frac{\partial p_i}{\partial Y} \frac{Y}{p_i} = \frac{\partial(\log p_i)}{\partial(\log Y)}$$

This measures elasticity and flexibility at a point, thus it is called the point elasticity or flexibility.

Measuring the elasticity of demand for a consumer good should be done preferably by using a designed equation based on prices at the retail level.

However, if these are not available then prices at the wholesale level should be used rather than at the primary market level. Using the primary market or wholesale level prices, yields an estimate of the lower limit of the elasticity of demand at the retail level. In general, two factors determine elasticity. The first is the availability of substitute goods. where the more and better substitutes for a specific good, the greater its price elasticity will tend to be. The second is the number of possible uses of the commodity, and the greater the number of uses to which the good may be put, the greater its price elasticity will be.

D. Substitutes and Complementary Goods

In constructing an individual demand schedule, the customary assumption is to hold money income, preference pattern and price of related commodities constant. If the prices of related commodities are allowed to vary, then quantity demanded of the good in hand will be affected in one way or the other. By observing these repercussions, one is able to classify commodities as complements or substitutes.

One way of classification is by cross-elasticity (total effect), where we can conclude that two goods are substitutes or complementary if the price cross-elasticity of demand is positive or negative respectively. There are advantages and disadvantages in using this way of classification. The other way of classification is by preference function. Hicks' definition of substitution and complementary goods refers to a disequilibrium situation. Using the indifference curve approach we can come up with Slutsky equation

$$\frac{\partial q_i}{\partial p_j} = \left(\frac{\partial q_i}{\partial p_j}\right)_{\bar{u}} - q_j \left(\frac{\partial q_i}{\partial y}\right)_{\overline{p's}}$$

We conclude from that, if $(\frac{\partial q_i}{\partial p_j})_{\bar{u}}$ is greater or smaller than zero, two goods are substitutes or complementary respectively.

E. Other Considerations

The use of deflated variables will eliminate the effect of change in general price level. The standard convention is to deflate prices by dividing them by the consumer price index. However, there is no standard technique of deflation which is applicable to all problems. Using the deflated data approach assumes that there is a one to one relationship between the original series and the deflator, and the deflation of a value index by a price index with fixed weights cannot yield a quantity index expressed in constant dollars of the base period.

The use of deflated series will not necessarily lead to more accurate results. Often the original and deflated series will lead to results that are more or less the same, however for some purposes, use of deflated data may be desirable. In any analysis it is important that the variables included be consistent.

The micro-economic theory is applied to the demand equations only in terms of relative prices. Thus correction of some manner for the effects of the general price level has to be done in order to determine whether a real correlation exists among prices of the individual commodities. However, it is hard to say whether this should be done by inclusion of the general price level as separate variable or by deflation.

III. STATISTICAL CONSIDERATIONS

A. Introduction

The statistical considerations relevant to this study are outlined in this chapter. Proofs of the mathematical relationships employed are not presented, however, references to relevant texts are given at points where such proofs may be desirable.

Multiple regression is used as a basic tool for analyzing these time series data. This technique is considered an important tool by many economists for forecasting and prediction. Although the availability of computer programs makes multiple regression analysis easier and avoids mistakes which might occur in hand computation, attention has to be given to the understanding of what multiple regression means and when it is applicable to the problem at hand.

Section B is devoted to the general regression techniques. Examination of the parameters and autocorrelation among residuals are discussed in Sections C and D, respectively. Sections E and F are devoted to a discussion of multicollinearity and dummy variables, respectively.

B. General Regression Techniques

1. Assumptions

If a linear relationship exists between variable Y (dependent) and p (independent) variables $X_1, X_2, \ldots, X_p$. A linear model of a form

$$Y_i = B_o + B_1X_{1i} + B_2X_{2i} + \ldots + B_pX_{pi} + U_i$$

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

is assumed.

We can express this model in matrix notation such as

$$Y = XB + U$$

where we define the following

1. Y to be a (n x 1) column vector of observations $Y_1, \ldots, Y_n$.
2. X to be a (n x p + 1) matrix of known form.
3. B to be a (p + 1 x 1) vector of unknown parameters.
4. U to be a (n x 1) vector of unknown errors.

$$Y = \begin{bmatrix} Y_1 \\ Y_2 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ Y_n \end{bmatrix} \qquad X = \begin{bmatrix} 1 & X_{11} & X_{21} & \cdots & X_{p1} \\ 1 & X_{12} & X_{22} & \cdots & X_{p2} \\ \cdot & \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdot & & \cdot \\ 1 & X_{1n} & X_{2n} & & X_{pn} \end{bmatrix}$$

$$B = \begin{bmatrix} B_o \\ B_1 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ B_p \end{bmatrix} \qquad U = \begin{bmatrix} U_1 \\ U_2 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ U_n \end{bmatrix}$$

Where the column of one's is used in the X matrix to represent the coefficient of the intercept term B_o, and where $U_i \sim N(0, \sigma^2)$. The elements of U are uncorrelated since

$$E(U) = 0$$

and $Var(U) = I \sigma^2$

2. Least square estimates

Since E (U) = 0, then the expectation of Y is E(Y) = XB. The error sum square is then

$$S^2 = U'U = (Y - XB)' \ (Y - XB)$$
$$= Y'Y - 2B'X'Y + B'X'Y \qquad (7)$$
$$= Y'Y - B'X'Y$$

The least squares estimate of B is a vector b which minimizes S^2 or U'U.

$$b = \begin{bmatrix} b_o \\ b_1 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ b_p \end{bmatrix}$$

Draper and Smith (4) show that by differentiating (7) with respect to B and setting the resultant equations = 0, we produce the normal equations (X'X)b = X'y, whose solutions are $b = (X'X)^{-1}X'y$, provided $(X'X)^{-1}$ exists. What is done here is to solve the (p + 1) linear equations for b_o, b_1, ..., b_p, (the (p + 1) estimates of unknown parameters). However, the solution in this form requires linear independence among the columns of (X'X) which must be full rank.

This condition may not be fulfilled so that (X'X) is singular, which means mathematically that the inverse matrix $(X'X)^{-1}$ does not exist. Then to obtain a solution either the model should be expressed in terms of fewer parameters or else additional restrictions on the parameters must be made.

So the vector $b = \begin{bmatrix} b_o \\ b_1 \\ . \\ . \\ . \\ . \\ b_p \end{bmatrix}$ is the least square estimate of $B = \begin{bmatrix} B_o \\ B_1 \\ . \\ . \\ . \\ . \\ B_p \end{bmatrix}$

Assuming $(X'X)^{-1}$ exist, then the vector $b = (X'X)^{-1}X'y$, has the following properties:

1. It is an estimate of B which minimizes the error sum of squares, S^2.

2. The elements of b are a linear function of the observations Y_1, Y_2, ..., Y_n and provide unbiased estimates of the elements of B, irrespective of distribution properties of the errors.

Assume we used the least square method to obtain the estimate b for B. We can find the following:

a. The prediction equation is $\hat{Y} = Xb$.

b. The residual vector $\hat{U} = (Y-Y)$.

c. Var (b) $= \sigma^2 (X'X)^{-1}$, provided the errors are independent.

Call the symmetric $(X'X)^{-1}$ matrix C which will be

$$\begin{bmatrix} C_{oo} & C_{o1} & \cdots\cdots & C_{op} \\ C_{10} & C_{11} & . & C_{1p} \\ C_{20} & C_{21} & \quad . & . \\ . & & \qquad . & . \\ . & & \qquad\quad . & . \\ . & & \qquad\qquad . & . \\ . & & \qquad\qquad\quad . & . \\ C_{po} & C_{p1} & \qquad\qquad\qquad . & C_{pp} \end{bmatrix}$$

So, Var $(b_i) = C_{ii}\ \sigma^2$, where

C_{ii} is the i^{th} diagonal term of C.

C. Examining the Estimates

After finding the estimates of the unknown parameters, we still have a problem of testing the significance of the resulting estimates.

In this section the tests of hypothesis concerning the significance of all parameters, the significance of a single parameter, testing the significance of different models, and the multiple correlation coefficient are discussed.

1. Testing the significance of all the parameters

In such a case the null hypothesis is

$$H_o:\ B_1 = B_2 \ . \ . \ . = B_p = 0$$

A test criterion is established to examine whether the data support the null hypothesis (H_o), or some class of alternative hypothesis such as K: not all zero. For such a test, the null hypothesis has to be specified precisely while the alternative may be just a class of possibilities.

Critical value is the value of the test statistic that determines the division between the two regions, one where the null hypothesis "H_o" is rejected and the other where H_o is not rejected. When the value of the test statistic exceeds the critical value, it is said to fall in the critical region. The decision of rejecting or not rejecting the H_o is based on probabilities and the kinds of errors that occur in the process of making a decision can be specified.

Now to carry out the test for the null hypothesis "H_o", it can be shown that the following test statistic has an F distribution with p, n-p-1 degrees of freedom under H_o.

$$F^* = \frac{b'X'Y - n\bar{y}^2/p}{Y'Y - b'X'Y/n-p-1} \sim F_{p,\ n-p-1}.$$

There are published tables of F values available, corresponding to specified levels of probabilities and different numbers of degrees of freedom.

When H_o is true F^* is $\backsim F_{p,\ n-p-1}$.

If F calculated (or F^*) exceeds the table values of F which is corresponding to the specific probability (say 0.01 or 0.05) i.e., if $F^* > F_{(.05)p,\ n-p-1}$; we reject the null hypothesis, and the set of coefficients is taken to be significant at that specified level of probabilities.

2. Test for a single coefficient

$$H_o: \ B_i = 0$$

$$t^* = \frac{b_i - 0}{S\sqrt{C_{ii}}} \backsim t_{n-p-1}$$

where C_{ii} is element corresponding to X_i in the principal diagonal of $(X'X)^{-1}$ and S is the estimate of the standard error. We can reject or fail to reject H_o if the t-table value for the mentioned degrees of freedom and the specified level of probabilities is smaller or greater, respectively.

3. Test of hypothesis that one model is not an improvement over another

Suppose we have two models, and one of them is more restricted than the other. The case of one model in which we do not allow change in intercept between the calendar quarters of the year and another model in which we use dummy variables to allow change in intercept between quarters is a good example for this kind of test.

Thus assume the more restricted model (Reduced model) could be written as

$$Y = B_o + B_1X_1 + B_2X_2 + \dots + B_pX_p + U \quad \text{(Reduced)}$$

and the less restricted model (full model) could be written as

$$Y = B_o + B_1X_1 + B_2X_2 + \dots + B_pX_p + B_{p+1}X_{p+1} + B_{p+2}X_{p+2} + z \quad \text{(full)}$$

Now the null hypothesis is

H_o: The less restricted (full) model is not an improvement over the restricted (reduced) model.

Thus the F test is

$$F_{m_1, m_2} \backsim \frac{\text{SS Residual (Reduced) - SS Residual (Full)/d.f. } (m_1)}{\text{SS Residual (Full)}/m_2}$$

where m_1 is the difference between the degrees of freedom under the reduced model and those of the full model, m_2 = n-p+1 d.f. [d.f. for the full model].

Again we will fail to reject H_o if F calculated is less than the F-value from the table under a certain level of probabilities which will mean that the full model is not an improvement over the reduced one. We will reject H_o if F calculated was greater than F table which will mean that the full model is an improvement over the reduced one.

4. Multiple correlation coefficient (R)

R^2 is an additional measure of the goodness of fit of the model and it is obtained by the ratio

$$R^2 = \frac{b'X'Y - n\bar{y}^2}{Y'Y - n\bar{y}^2} \qquad \frac{\text{Sum of squares due to regression}/B_o}{\text{Total (corrected) sum of squares}} .$$

R^2 is an extension of the quantity defined for the straight line regression and is called also "coefficient of multiple determination". $R^2 = 1$ if $\hat{Y}_i = Y_i$, indicating the prediction is perfect. $R^2 = 0$ if $\hat{Y}_i = \bar{Y}$ that is $b_1 = \ldots = b_p = 0$. We can consider R^2 as a measure of the success of the regression equation in explaining the variation in the data, and a measure of the usefulness of the terms other than B_o in the model.

D. Autocorrelation Among The Residuals

One of the assumptions used before was that serial independence exists among the disturbance term, which was implied in

$$E(UU') = \sigma^2 I$$

and which gives

$$E(U_t \; U_{t+s}) = 0 \qquad \text{For all } t \text{ and all } s \neq 0$$

In some cases this assumption does not hold. For example, when specifying an incorrect form of the relation between the variable, i.e., using linear form when the quadratic form is the correct one. The measurement error in the explained variable also will be included in part in the disturbance term, which may become a source of autocorrelation. We usually include just certain variables in the specified relation, i.e., the ones we believe are most important explanatory variables. The residuals, on the other hand, represent the influences of any omitted variable that may have an effect on explaining this relation. Thus, omitting a variable which may have some influence will be considered as another source for causing autocorrelation among the residuals.

If assuming our original equation is

$$Y_t = A + B\,X_t + U_t \tag{8}$$

and if assuming that first-order autoregressive scheme exists between the disturbances term, then it could be introduced as

$$U_t = \rho U_{t-1} + e_t$$

where $|\rho| < 1$

and e_t satisfy the assumptions

$$E(e_t) = 0$$

$$E(e_t e_{t+s}) = 0 \qquad s \neq o \text{ for all } t$$

$$E(e_t e_{t+s}) = \sigma_e^2 \qquad s = o \text{ for all } t,$$

which means that the e's are uncorrelated random variables with mean zero and variance σ_e^2.

Johnston (16) showed that the above concludes to

$$E(U_t U_{t-1}) = E\left[(e_t + \rho e_{t-1} + \rho^2 e_{t-2} + \ldots)(e_{t-1} + \rho e_{t-2} + \rho^2 e_{t-3} + \ldots)\right]$$

$$= \rho E\left[(e_{t-1} + \rho e_{t-2} + \ldots)^2\right]$$

$$= \rho\,\sigma_U^2$$

in general $E(U_t U_{t-s}) = \rho^s\,\sigma_U^2 \qquad s \neq o$

So, the relation specified in (8) does not satisfy the assumption of independency among the residuals.

The autocorrelation coefficient of the U series could be written as

$$\frac{E(U_t\ U_{t-s})}{\sigma_U^{\ 2}} = \rho^s$$

The autocorrelation coefficient of zero order (s=o) for any series is unity, and for a random series all coefficients of higher order (s≠o) will be zero.

1. Tests against autocorrelation

The Durbin-Watson statistic. To test autocorrelation presence in any time series regression, the null hypothesis is that randomness exists between the successive disturbances (positive autocorrelation = 0), against an alternative hypothesis that positive autocorrelation exists among them, which means that the successive disturbances are positively correlated.

To clear the idea behind the Durbin-Watson statistic, consideration is given to the following equation

$$E(U_t - U_{t-1})^2 = Ee_t^{\ 2} + Ee_{t-1}^{\ \ 2} - 2E(e_t\ e_{t-1})$$

If there is no positive correlation between the residuals (residuals are uncorrelated), the expectation in the left hand side will be greater than if the successive disturbances were positively correlated -- that is because of the negative sign of $-2E(e_t\ e_{t-1})$. Assuming that U_1, ..., U_n are satisfactory approximations of the corresponding residuals, this will lead to the Durbin-Watson statistic

$$d = \frac{\sum_{t=2}^{n} (U_t - U_{t-1})^2}{\sum_{t=1}^{n} U_t^{\ 2}}$$

To avoid complication in the application procedures, Durbin and Watson (1950-51) formulated (d_L, d_u) bounds for each limit lies in this interval whatever X may be. The procedure followed then, is to reject the null hypothesis (which states the randomness of successive disturbances) if $d < d_L$; if $d_u > d > d_L$ we draw no conclusion, and we declare failing to reject the null hypothesis if $d > d_u$. There are published tables containing those limits with certain numbers of observations and certain numbers of variables (including the intercept).

There are some difficulties in applying such a test, since when the number of observations is modest and K is not very small, the inconclusive range (d_L, d_u) is sometimes large. Another difficulty is that this interval limit may differ from the exact significant limit (which depends on the X matrix of the regression). In the cases where the behavior of the explanatory variables is smooth, in the sense that their first and second differences are small compared with the range of the corresponding variable itself, Theil and Nagar (1961) showed that the upper limit d_u is approximately equal to the true significance limit. Some other work has been done by Durbin and Watson (1951) to describe an approximation method for obtaining conclusive results when d falls in (d_L, d_u) but there is little experience with this procedure.

The von Neumann ratio is a well known statistic for testing against autocorrelation. This statistic is defined as the ratio of the mean square successive difference to the variance. The von Neumann ratio is closely related to the Durbin-Watson statistic. When the ratio is sufficiently large (small), it indicates negative (positive) autocorrelation.

If the straightforward least square formula is applied, as Johnston (16) stated it, there will be three consequences for autocorrelation:

1. The estimates of α and β are unbiased, but the sampling variance of these estimates may be unduly large compared with those achievable by a slightly different method of estimation.

2. Applying the usual least square formulas for the sampling variances of the regression coefficient, it is likely to obtain a serious underestimate of these variances. In any case these formulas are no longer valid, nor are the precise forms of the t and F tests derived for the linear model of Section 2.

3. Inefficient predictions are obtained, that is, predictions with needlessly large sampling variance.

2. Autocorrelation and autoregressive transformation

Assuming the first order Markov scheme holds among the disturbance term, it has been shown by Theil (34) that if T is defined as the transformation matrix, where the transformed variables indicated by T are

$$\sum_{i=2}^{n} y_i - \rho y_{i-1} = \begin{bmatrix} y_2 - \rho y_1 \\ y_3 - \rho y_2 \\ \cdot \\ \cdot \\ \cdot \\ y_n - \rho y_{n-1} \end{bmatrix} \quad \text{and} \quad \sum_{i=2}^{n} X_i - \rho X_{i-1} = \begin{bmatrix} X_2 - \rho X_1 \\ X_3 - \rho X_2 \\ \cdot \\ \cdot \\ \cdot \\ X_n - \rho X_{n-1} \end{bmatrix}$$

and if apply T to the relation $Y = XB + u$, to give $TY = TXB + Tu$, then the simple least square estimator of B using transformed variable is

$$\begin{aligned} B^* &= \left[(TX')(TX)\right]^{-1} (TX)'(TY) \\ &= (X'T'T\,X)^{-1} X'T'TY \end{aligned}$$

The variance-covariance matrix for the disturbances is

$$E\left[(TU)(TU)'\right] = TVT'$$

$$= e^{2} \begin{bmatrix} 1 & 0 & 0 \\ . & 1 & . \\ . & . & . \\ 0 & 0 & 1 \end{bmatrix}$$

and the simplest least square estimator is chosen to minimize

$$(Y - Xb)' \, T'T \, (Y - Xb)$$

which is almost like $(Y - Xb)' \, V^{-1} \, (Y-Xb)$ [except for the 1^{st} row and 1^{st} column of TT' and V^{-1}] which is minimized by the generalized least square estimator.

3. First differences transformation

If the residuals are suspected to follow a first-order Markov scheme and when ρ is known, it is a straightforward procedure to transform the original variables, then apply simple least square to the transformed data. In the absence of such knowledge, one can assume that ρ is around unity. In such case the approximation of $\rho = 1$ will lead to the first difference transformation,

$$\Delta y_i = \sum_{k=1}^{p} B_\alpha \, \Delta X_{ik} + D \, u_i$$

where $\Delta y_i = y_i - y_{i-1}$, etc. $i = 2, \ldots, n.$

On one hand, using first difference procedure will lead to further misspecification if a second or higher order autoregressive scheme is involved. On the other hand, it has been suggested that if ρ is smaller than or equal to 0.39, the use of first difference transformation will increase the autocorrelation.

As a conclusion it was seen that by using simple least square procedures to estimate the parameters of any relation where autocorrelation exists between the successive disturbances, we will obtain unbiased estimators, but their sampling variances will be seriously underestimated, and it is not by any means a minimal.

4. Best linear unbiased prediction

Suppose the prediction equation is

$$\hat{Y} = X_* B + U_*$$

As was shown before, the LS predictor value of $\hat{Y}$ is $X_*\hat{B}$ and the immediate extention GLS is thus X_*B^*. However the better predictor could be obtained when GLS residual vector Y - XB* is taken into account, since the other predictor neglects the disturbance component u_* of $\hat{y}$, and also since u_* and u of the sample period is correlated.

Availability of ρ will enable us to write

$$y_t - \rho y_{t-1} = \alpha(1-\rho) + B(X_t - \rho x_{t-1}) + e_t$$

which satisfies all the assumptions of a simple linear model, and which is clearly a direct application of LS to the transformed variables. This equation is superior in prediction than the first one.

It was shown by Goldberger (1961) that given $X_{n+s,1}, \ldots, X_{n+s,p}$ the best linear unbiased predictor of y_{n+s} based on observation matrix $[X\ Y]$ is

$$\sum_{k=1}^{p} \hat{B}_k X_{n+s,k} + \rho^s \left(y_n - \sum_{k=1}^{p} \hat{B}_k X_{n,k}\right) \tag{9}$$

where B is the GLS coefficient vector. However, it is worth noting that the GLS residual of the sample that occurs in this equation is the last (the n^{th}).

E. Multicollinearity

Multicollinearity is one of the problems associated with any economic data. It exists when intercorrelation is present between any of the explanatory variables (X's). When such problems exist it will cause (XX') matrix to be singular which means that the inverse matrix $(XX')^{-1}$ does not exist, which in turn means that LS estimators do not exist. In real life problems a perfect correlation between two variables seldom exists, but it is usual to see explanatory variables that are highly correlated which will also lead to greater standard errors.

By experience it was shown that by facing such a problem it is better to regress one variable over the other than to remove one of them from the model. This problem is quite clear when we use time trend as a variable with income and prices. To illustrate such a procedure suppose two explanatory variables are presented, namely X_2, X_3 (where X_3 is a time trend variable) which are highly correlated. Thus to eliminate the effect of this intercorrelation X_3 is regressed on X_2

$$X_2 = a + b\, X_3 + e$$

where $E(X_3 e) = 0$ and where $e = X_2 - \hat{X}_2$ for all the observations. The new variable is defined as "the derivation of X_2 from trend". This new required variable has the property of not being correlated with X_3 (time). Thus in the original model this new variable could be used beside X_3 to give better fit.

F. Dummy Variables and Their Advantages

There are many advantages of using dummy variables in economic analysis, especially when it is believed that the periods are not homogeneous in the single analysis. In such cases it is hard to set up a continuous scale for the variable. Some levels have to be assigned to these variables in order to take account of the fact that the various variables may have separate deterministic effects on the response.

It has been useful to use dummy variables in quarterly observations which require some adjustment for possible seasonal effect. It has been common to use zero-one variables - simple covariance model to represent dichotomous variables that are indirectly observable. Dummy variables can be used also to allow the change in slopes. However, the technique of using dummy variables will help in increasing the degrees of freedom, give an estimation of the coefficient estimation for each quarter exactly equal to the coefficient estimates obtained from separate functions for each equation, and to remove the linear trend in situations where predictions are to be made for a future time period. They also can be used to reduce the time and cost for an economic analysis.

IV. ANALYTICAL PROCEDURES

A. Introduction

The economic and statistical considerations relevant to the study were presented in the previous chapters. In this chapter these theoretical considerations are applied to build the framework and to represent the analytical procedures for the study. Some of the considerations were not explicitly used, however it will remain within the framework of the analysis.

The variables used are specified in Section B. Sections C and D are devoted to discussion of the models, the hypotheses and their test of significance respectively. The models and the hypotheses concerning the effect of the supply levels are discussed in Section E. Section F is devoted to the data and its original sources.

B. The Variables

To construct the models which are used to test the specified hypotheses, many subsets of the following groups of variables have been used.

1. Price of live hogs, Omaha - dollars per 100 wt.
2. Per capita civilian consumption of meat and poultry - pounds.
3. Per capita disposable income - current dollars.
4. Consumer price index - 1957-59 = 100.
5. Farm - wholesale margin for pork - cents per lb.
6. Dummy variables.
7. Other variables.

The prices in the first group are used as dependent variables in all the constructed models. Prices were computed from available weekly data, then the quarterly data used in the study were constructed by using the simple average method. Per capita variables in the second and third groups are used to eliminate the effect of change in the population. Four kinds of meats were used under the second group, namely, per capita consumption of pork, beef, broiler and turkey which are considered as consumption variables for own commodity (pork) and the closely related (close substitute) commodities respectively. Per capita civilian consumption of pork and beef are in carcass weight, broiler and turkey are lb. ready to cook weight. The fourth group of variables was used as a deflator for all variables under the first, third and fifth groups, in some models of the study, to eliminate the effect of change in general price level. The sixth group of variables was used in the form of (0, 1) to allow for change in intercept between quarters, and was used later in the study to allow for change in intercept between different levels of supply. The seventh group of variables, namely, "other variables", contains some additional variables constructed and used in the study. It was clear from earlier work in the study that high intercorrelation exists between per capita disposable income and time trend variables. Thus, the "deviation of income from time trend" variable was constructed and used. When the nonlinear version of the models was used, this variable was defined as "the deviation of the logarithm of income from the logarithm of time trend". As mentioned before, the main reason for using such variables is to eliminate the high intercorrelation between variables. It was expected that in the logarithm or nonlinear version of the models, this new variable would have the correct property of being uncorrelated with the trend variable.

C. The Models

Three basic models were constructed using subsets of the groups of variables discussed before. For each model four equations were used; in two of them variables measured in current dollar were used (nominal), one in linear form and the other in nonlinear form. The other two equations were constructed using the same variables deflated by the consumer price index, also one of them in linear form and the other in the nonlinear form. Thus twelve equations were used in describing the three basic models, six of them using variables measured in current dollars (3 linear and 3 nonlinear). Another six equations were applied to the three basic models using deflated variables (3 linear and 3 nonlinear). Comparisons were made of the results obtained from fitting the nominal equations with the deflated ones for each model.

These twelve equations were constructed after solving the multicollinearity problem between income and time trend variables. However, in all twelve equations the Durbin-Watson statistic was low (see Section 1, page 21), which gave an indication of the existence of positive autocorrelation among the residuals. A procedure to reduce or eliminate the autocorrelation was needed. One alteration by means of ρ_1 was used in this respect to transform the original variables for the twelve equations. This gave another twelve equations -- four for each model. The twelve equations (using transformed variables) were compared with the previous twelve equations before transformation.

The time period used in the analysis includes the first quarter of 1955 through the fourth quarter of 1970; thus there are 16 years with 64 quarterly observations. Since autoregressive least square technique was used to transform the original variables, 1 degree of freedom was lost as a result of this transformation. In such cases 63 observations were used.

The three basic models are presented in the transformed form, although the same models were fitted to the original variables only for the purpose of comparison.

1. Model I

This is the most restricted model, where no allowance is made for any change in intercept or slopes between quarters. The linear form of this model (I-a), using variables measured in current dollar, could be written as

$$P'_{P_i} = B_{i_o} + B_{i_1} C'_{P_i} + B_{i_2} C'_{B_i} + B_{i_3} C'_{BR_i} + B_{i_4} C'_{TR_i} + B_{i_5} M'_{FW_i} + B_{i_6} T'_i + B_{i_7} V'_i + e_i \qquad \text{I - a}$$

where $P'_{P_i} = (P_{P_i} - \hat{\rho} P_{P_{i-1}})$, $C'_{P_i} = (C_{P_i} - \hat{\rho} C_{P_{i-1}})$, $C'_{B_i} = (C_{B_i} - \hat{\rho} C_{B_{i-1}})$ .... etc., and where e_i represents the residuals after transformation. Notations P, C, m, T and V refer to price, per capita consumption, margin for pork, time trend and deviation of income from trend variable respectively. The subscripts p, B, BR, TR and FW refer to pork, beef, broiler, turkey and farm-wholesale respectively. This model has n-p-1 d.f. = 63-7-1 = 55 d.f., where i = 2, ..., 64.

The nonlinear version of this model could be written as

$$\ln P'_{P_i} = B_{i_o} + B_{i_1} \ln C'_{P_i} + B_{i_2} \ln C'_{B_i} + B_{i_3} \ln C'_{BR_i} + B_{i_4} \ln C'_{TR_i} + B_{i_5} \ln m'_{FW_i}$$

$$+ B_{i_6} \ln T'_i + B_{i_7} V_{i_*} + e_{i_*} \qquad \text{I - b}$$

where the notation and subscripts are the same as before, and V'_i is the "deviation of the logarithm of income from the logarithm of time trend".

The deflated price, margins and deviation of deflated income from time trend variable are represented by P^*_p, $M^{*'}_{FW}$ and $V^{*'}$ respectively. Using these deflated variables in linear form, the model could be written as

$$P^{*'}_{P_i} = B_{i_o} + B_{i_1} C'_{P_i} + B_{i_2} C'_{B_i} + B_{i_3} C'_{BR_i} + B_{i_4} C'_{TR_i} + B_{i_5} M_{FW_i}$$

$$+ B_{i_6} T'_i + B_{i_7} V^{*'}_i + e^*_i \qquad \text{I - c}$$

where the notations and subscripts are the same as before. The nonlinear version of this equation is

$$\ln P^{*'}_{P_i} = B_{i_o} + B_{i_1} \ln C'_{P_i} + B_{i_2} \ln C'_{B_i} + B_{i_3} \ln C'_{BR_i} + B_{i_4} \ln C'_{TR_i} + B_{i_5} \ln M^{*'}_{FW}$$

$$+ B_{i_6} \ln T'_i + B_{i_7} V^*_{i*} + e^*_{*_i} \qquad \text{I - d}$$

and where V^*_{i*} = the deviation of the logarithm of deflated income from the logarithm of time trend variable. The other notations and subscripts are the same as before. All of these first model forms have 55 d.f.

2. Model II

This model is less restrictive than the first model. Allowance is made for a change in intercept between quarters but not in slopes. The intercept is allowed to vary between quarters by introducing three dummy variables in the form of (0, 1) such as:

$D_2 = 1$ for second quarter, zero otherwise.

$D_3 = 1$ for third quarter, zero otherwise.

$D_4 = 1$ for fourth quarter, zero otherwise.

It was shown by a means of a correlation matrix that there is a very low correlation between these original dummy variables and the transformed ones. So the transformed dummy variables were used in the prediction models.

The linear form of Model II, using variables measured in current (nominal) dollars could be written as:

$$P'_{P_i} = B_{i_o} + B_{i_1} C'_{P_i} + B_{i_2} C'_{B_i} + B_{i_3} C'_{BR_i} + B_{i_4} C'_{TR_i} + B_{i_5} M'_{FW_i} + B_{i_6} T'_i$$

$$+ B_{i_7} V'_i + B_{i_5} D'_2 + B_{i_9} D'_3 + B_{i_{10}} D'_4 + e_i \qquad \text{II - a}$$

where the notations and subscripts are the same as before. All the forms of Model II have 63-10-1 = 52 d.f. In this model the intercept coefficient for the first quarter is equal to the model's intercept coefficient. The intercept coefficients for the second, third and fourth quarter are equal to the intercept coefficient of the model plus the coefficient of D'_2, D'_3 and D'_4 respectively.

The nonlinear version of II-a could be written as:

$$\ln P'_{P_i} = B_{i_{o*}} + B_{i_1} \ln C'_{P_i} + B_{i_2} \ln C'_{B_i} + B_{i_3} \ln C'_{BR_i} + B_{i_4} \ln C'_{TR_i} + B_{i_5} M'_{FW_i}$$

$$+ B_{i_6} \ln T'_i + B_{i_7} V'_{i_4} + B_{i_B} D'_2 + B_{i_9} D'_3 + B_{i_{10}} D'_4 + e_{i_4}$$

$$\text{II - b}$$

where the notations and subscripts are the same as before.

Using the deflated variables, i.e., $P^{*\prime}_{p_i}$, $M^{*\prime}_{FW_i}$ and $V^{*\prime}_i$ the linear (II-c) and nonlinear form (II-d) could be written as before using the same other variables, notations and subscripts.

3. Model III

This model is less restricted than the previous models. In this model allowance is made for a change in the intercept and slopes between quarters. The linear form for such model, using variables measured in current dollars, could be written as

$$\begin{aligned} P'_{p_i} = {} & B_{i_o} + B_{i_1} C'_{p_i} + B_{i_2} C'_{B_i} + B_{i_3} C'_{BR_i} + B_{i_4} C'_{TR_i} + B_{i_5} M'_{FW_i} + B_{i_6} T'_i \\ & + B_{i_7} V'_i + B_{i_8} D'_2 + B_{i_9} D'_3 + B_{i_{10}} D'_4 + B_{i_{11}} (C_{p_i} \cdot D_2)' \\ & + B_{i_{12}} (C_{p_i} \cdot D_3)' + B_{i_{13}} (C_{p_i} \cdot D_4)' + e_i \qquad \text{III - a} \end{aligned}$$

where the last three variables are introduced to allow for a change in the slope between quarters. These are simply the product of multiplying C_{p_i} by D_2, D_3 and C_4 respectively. In this model the intercepts vary in the same way as explained before, and the slope coefficient of the first quarter is equal to the coefficient of C'_{p_i} variable. The slope coefficients for the 2nd, 3rd, and 4th quarters are then the coefficient of the variable C'_{p_i} plus the coefficients of $(C_{p_i} \cdot D_2)$, $(C_{p_i} \cdot D_3)$ and $(C_{p_i} \cdot D_4)$ respectively. This model has 63-13-1 = 49 d.f., and the notations and subscripts are the same as before.

The nonlinear version of such equation could be written as

$$\ln P'_{P_i} = B_{i_{o*}} + B_{i_1} \ln C'_{P_i} + B_{i_2} \ln C'_{B_i} + B_{i_3} \ln C'_{BR_i} + B_{i_4} \ln C'_{TR} + B_{i_5} \ln M'_{FW_i}$$
$$+ B_{i_6} \ln T'_i + B_{i_7} V'_i + B_{i_8} D'_2 + B_{i_9} D'_3 + B_{i_{10}} D'_4 + B_{i_{11}}$$
$$(\ln C_{P_i} \cdot D_2)' + B_{i_{12}} (\ln C_{P_i} \cdot D_3)' + B_{i_{13}}$$
$$(\ln C_{P_i} \cdot D_4)' + e_{i*} \qquad \text{III - b}$$

where the same notations and subscripts are used again. In this form both the intercept and sloped flexibility are allowed to change between quarters.

Using the deflated variables, i.e., $P^{*\prime}_{P_i}$, $M^{*\prime}_{FW_i}$ and $V^{*\prime}_i$ the linear (III-c) and nonlinear (III-d) form of this model could be written as before using the same variables, notations and subscripts.

Under each model comparisons were made of the results and goodness of fit obtained from fitting the forms with variables measured in current (nominal) dollars and the results with deflated variables. Another comparison was made between the linear and nonlinear form for each.

D. The Hypotheses and Tests of Significance

Constructing the models in the previous forms, it is a straightforward procedure to achieve the second secondary objective by testing the following null hypotheses.

1. There is no significant difference (change) in intercept between quarters. [Model II is not an improvement over Model I.]

2. There is no significant difference (change) in slopes between quarters. [Model III is not an improvement over Model II.]

Model I and Model II are used to test the first hypotheses, Models II and III are used to test the second hypotheses. Each set of equations is used separately, i.e., I-a, II-a and III-a. Thus every hypothesis is tested four times, once for each set of equations, i.e., a, b, c and d. The sum of squared residuals for the logarithmic function is obtained by finding the antilogarithm of the predicted values, then subtracting the actual value and squaring and summing the differences.

To carry out the test for the first hypothesis, the discussion in Section 3, page 18 is followed. The F test of homogeneity is

$$F^{m_1}_{m_2} = \frac{\text{SS Residual (Reduced) - SS Residual (Full)}/m_1}{\text{SS Residual (Full)}/m_2}$$

where the reduced model is the more restricted one, namely, Model I, and the full model is Model II, the less restricted one, and where

m_1 = d.f. of Model I - d.f. of Model II = 55-52 = 3 d.f.

m_2 = d.f. of the full model (Model II) = 52 d.f.

The calculated F value was compared with the F value from the published table using the appropriate degrees of freedom under specified levels of probabilities (i.e., 0.05). We reject or fail to reject the null hypothesis if the F-calculated value is greater or smaller than the F-table value respectively. If the null hypothesis is rejected, this means that Model II is superior over Model I.

To test the second hypotheses, the same test is carried out. But here the reduced model is Model II and Model III (the less restricted model) is the full model. Accordingly, m_1 is equal to 52-49 = 3 d.f., and m_2 (which stands for the degrees of freedom of Model III) is equal to 49 d.f. We reject or fail to reject the null hypothesis according to the same rule as before.

E. The Models and Hypotheses Concerning the Effect of the Supply Levels

The third secondary objective was to study the effect, if any, of different levels of supply (i.e., per capita consumption of pork) on the supply-price relationship for hogs at the primary market. To do this, the level of per capita consumption of pork for each quarter was classified to three different levels, i.e., high, medium and low. The medium level contains those values around the mean, the high and low levels contain those values greater and lower than those values around the mean for each quarter respectively. The other step to achieve this objective was to use three other models. From testing the previous hypotheses, Model II appeared to be the most acceptable one to use. Therefore, this model was considered as the more restricted model in this stage, where allowance was made only for the change in the intercept between quarters. The four equations of Model II (i.e., II-a, b, c and d) were used in this respect with the same degrees of freedom. Two other models were constructed.

4. Model IV

This model is less restricted than Model II. In this model allowance is made for a change in the intercept between high, medium and low levels of supply. This change was allowed by introducing another two dummy variables in the form of (0, 1) such as

$H = 1$ for high level of supply, zero otherwise.

$L = 1$ for low level of supply, zero otherwise.

where every observation is classified as high, medium or low compared to the mean value of its specific quarter, then assigned a value of one or zero accordingly.

Using the same notations and subscripts as before, the linear form for this model, using variables measured in current (nominal) dollars could be written as

$$P'_{P_i} = B_{o_i} + B_{i_1} C'_{P_i} + B_{i_2} C'_{B_i} + B_{i_3} C'_{BR_i} + B_{i_4} C'_{TR} + B_{i_5} M'_{FW} + B_{i_6} T'_i + B_{i_7} V'_i + B_{i_8} D'_2 + B_{i_9} D'_3 + B_{i_{10}} D'_4 + B_{i_{11}} H' + B_{i_{12}} L' + e_i \qquad \text{IV - a}$$

where the other two variables are the new dummy variables introduced above. This model has n-p-1 d.f. (63-12-1 = 50 d.f.).

The nonlinear version of this form could be written as

$$\ln P'_{P_i} = B_{i_{o*}} + B_{i_1} \ln C'_{P_i} + B_{i_2} \ln C'_{B_i} + B_{i_3} \ln C'_{BR_i} + B_{i_4} \ln C'_{TR_i} + B_{i_5} \ln M'_{FW} + B_{i_6} \ln T'_i + B_{i_7} V'_{i*} + B_{i_8} D'_2 + B_{i_9} D'_3 + B_{i_{10}} D'_4 + B_{i_{11}} H' + B_{i_{12}} L' + e_{i*} \qquad \text{IV - b}$$

The linear and nonlinear forms IV-c and IV-d of this model using deflated variables, i.e., $P*'_{P_i}$, $M*'_{FW}$ and $V*'_i$ could be stated as before with the same degrees of freedom, i.e., 50 d.f.

5. Model V

This is the less restrictive model for this stage where allowance is made for a change in the intercept and slopes between high, medium and low levels of supply. The linear form of this model using variables measured in current (nominal) dollars could be written as

$$P'_{P_i} = B_{i_o} + B_{i_1} C'_{P_i} + B_{i_2} C'_{B_i} + B_{i_3} C'_{BR_i} + B_{i_4} C'_{TR_i} + B_{i_5} M'_{FW_i} + B_{i_6} T'_i$$
$$+ B_{i_7} V'_8 + B_{i_8} D'_2 + B_{i_9} D'_3 + B_{i_{10}} D'_4 + B_{i_{11}} H' + B_{i_{12}} L'$$
$$+ B_{i_{13}} (C_{P_i} \cdot H)' + B_{i_{14}} (C_{P_i} \cdot L)' + e_i \qquad \text{V - a}$$

where the last two variables are introduced to allow the slope to vary within each quarter. These variables are merely the product of multiplying the C_{P_i} variable by H and L respectively. The same notations and subscripts were used as before. This model has 63-14-1 = 48 d.f.

The nonlinear version of this form, using the same notations and subscripts could be written as

$$\ln P'_{P_i} = B_{i_o} + B_{i_1} \ln C'_{P_i} + B_{i_2} \ln C'_{B_i} + B_{i_3} \ln C'_{BR_i} + B_{i_4} \ln C'_{TR_i} + B_{i_5} \ln M'_{FW}$$
$$+ B_{i_6} \ln T'_i + B_{i_7} V^*_{i*} + B_{i_8} D'_2 + B_{i_9} D'_3 + B_{i_{10}} D'_4 + B_{i_{11}} H'$$
$$+ B_{i_{12}} L' + B_{i_{13}} (\ln C_{P_i} \cdot H)' + B_{i_{14}} (\ln C_{P_i} \cdot L)' + e_{*i}$$

V - b

The linear and nonlinear form of the model using deflated variables, i.e., $P^{*\prime}_{P_i}$, $M^{*\prime}_{FW}$ and $V^{*\prime}_i$, could be written and identified as V-c and V-d respectively with 48 d.f.

Again, stating the models in this way, it is easy to test the following null hypotheses:

A. There is no significant difference (change) in the intercept between high, medium and low level (Model IV is not an improvement over Model II).

B. There is no significant difference (change) in the slopes between high, medium and low levels (Model V is not an improvement over Model IV).

The F test of homogeneity was used again to test these hypotheses (see Section 3, page 18). For testing hypothesis A, Model II was tested against Model IV where the former and the latter were considered as the more restricted (reduced) and less restricted (full) models respectively. In this case, m_1 is equal to 52-50 = 2 d.f., and m_2 = 50 d.f. The test for hypothesis B was carried out using Model IV as the restricted model and Model V as the full model with m_1 = 2 d.f. and m_2 = 48 d.f. Each of these hypotheses was tested four times, i.e., one test for each set of equations (II-2, IV-a; II-b, IV-b; ..., ; IV-d, V-d) and the same rule to reject or fail to reject the null hypothesis was used as before.

F. The Data

Quarterly time series data for the sample period under analysis, starting from the 1st quarter of 1955 through the 4th quarter of 1970, are included in the Appendix. The description of this data is as follows:

A. Price of live hogs (all barrows and gilts), Omaha, doll. per 100 wt.

B. Pork farm-wholesale margin, cents per lb.

C. Per capita personal disposable income, current dollars.

D. Consumer price index, all items 1957-59 = 100.

E. Per capita civilian consumption of pork, beef (lbs., carcass weight), broilers and turkey (lbs., ready-to-cook weight).

The original sources for this data, the portion of the time series contributed by each source and the needed adjustment, if any, are presented in Table 1.

Table 1. The data: original sources and manipulation

Data heading	Period	Source	Adjustment
A.	1955 to 1958	(38)	d[a], 2[b]
	1959 to 1969	(39)	d[a], 2[b]
	1970	(39)	d[a], 3[c]
B.	1955 to 1970	(36, pp. 22, 24, 25)	d[a]
C.	1955 to 1970	(40, p. 11)	d[a]
D.	1955 to 1970	(43)	
E. Pork	1955 to 1963	(35, p. 60)	
	1964 to 1966	(33, p. 89)	
	1967 to 1970	(34, p. 35)	
Beef	1955 to 1963	(35, p. 60)	
	1964 to 1966	(33, p. 89)	
	1967 to 1970	(34, p. 35)	
Broiler	1955 to 1959	(33, p. 90)	
	1960 to 1970	(34, p. 36)	
Turkey	1955 to 1959	(33, p. 90)	
	1960 to 1970	(34, p. 36)	

[a]These data were used in their nominal (current) values and were deflated by the data in Group D in some models of the study.

[b]Data available on a monthly basis and was converted to quarterly basis.

[c]Data available on a weekly basis and was converted to quarterly basis.

The data under heading A, B and C were used in their nominal (current) value and were also deflated by Group D (consumer price index 57-59 = 100) in some models of the study. The quarterly data under Group A were obtained by computing the simple average from the available monthly data from 1955 to 1969 and from the available weekly data for 1970. The per capita civilian consumption data for pork and beef are in carcass weights and includes processed meat on fresh equivalent basis.

V. EMPIRICAL RESULTS

A. Introduction

The empirical results presented in this chapter were obtained following the analytical procedures discussed in Chapter IV. The study is devoted to an analysis of the price-quantity relationship for hogs at the primary market level, following the three identified areas of analysis discussed in Chapter I.

The final form of the models discussed in the previous chapter are the result of many trials, using the backward elimination process. The wholesale margin for pork and per capita consumption of lamb variables were omitted since they were not significant at the 5 or 1 percent levels and since they did not add to the R^2 value. The intercorrelation between per capita disposable income and the time trend variable was 0.96 which indicates the presence of high correlation. The deviation of income variable was introduced to the model, along with the time trend variable, as an alternative for the per capita disposable income variable (Section D, page 19). However, after specifying the relationship as presented in the last chapter, the autocorrelation between the successive disturbances was tested. Low Durbin-Watson statistic indicated positive autocorrelation between the residuals. Thus the original variables were transformed using autoregressive least square method by means of $\hat{\rho}$ coefficient to reduce the autocorrelation. Tables on the Durbin-Watson statistic are limited to smaller range of variables than those used in the study. This limitation is partially solved by expanding the table to a few more variables using the same range between D_L and D_u for the small number of variables indicated in such tables. The results of Durbin-Watson tests were satisfactory in spite of this limitation.

The models using transformed variables have superior characteristics for prediction purposes than the models with original variables (Section C, page 16). The latter models are presented along with the former only for comparison purposes. Thirty-two equations are discussed in this chapter, with the price of hogs used as the dependent variable in all cases.

Section B is devoted to the results of fitting Models I, II and III with the implications of these results and comparison between the models with original and transformed variables. Also presented in this section is the empirical evidence of seasonal variation in the level of demand between quarters and the results of F-tests of homogeneity to establish a set of equations of superior fit for this stage. Section C is concerned with the empirical results of fitting Models IV and V, and with the empirical evidence about the effect of changes in the level of supply of pork on the level and slope of the demand curve for live hogs. This section is also concerned with the results of F-tests of homogeneity to establish the final set of equations that were found to be of superior fit over all the others. The direct and cross price flexibilities and empirical results of using the best model in forecasting are presented in Section D and Section E respectively.

B. Empirical Results for Models I, II and III

Twenty-four equations are presented in this section. They are classified in two groups, twelve equations in each group. In the first group the three models are fitted using the original variables, four equations for each model. Two of them use variables measured in current dollars in linear form and nonlinear form. In the other two equations, deflated variables are used in both linear and nonlinear forms. The second group contains the models fitted using transformed variables and has the same sequence of equations as in the first group.

Table 2 shows the resultant regression coefficients, their T-values and their significance at the 5 and 1 percent levels. Also presented in the table are the various measures of fit for the equations, i.e., the coefficient of multiple determination - R^2 -, F-test of overall significance of the variables and sum of squared residuals. The Durbin-Watson statistics are presented with the relevant $\hat{\rho}$ coefficients and their significance at 5 and 1 percent levels for each transformed fit. Letter - B - (i.e., before transformation) is used to identify equations where the original variables were used; on the other hand, letter - A - (i.e., after transformation) is used to identify the equations where the transformed variables were used. The equations representing nominal-linear, nominal-nonlinear, deflated-linear, and deflated-nonlinear are represented by letters a, b, c and d respectively.

The regression coefficients for the consumption variables are expected to have negative signs unless dominated by strong income effect. The coefficients of the first model are all significant at 5 percent level. The per capita consumption of turkey variable has a positive coefficient in Model I, indicating that turkey is complementary with pork, however, it is highly significant at 5 percent level. Fitting the linear equations of Model I (i.e., Groups a and c) after omitting the per capita consumption

Table 2. Estimated coefficients for Models I, II and III

	R^2	Durbin-Watson	F-Ratio	SS Resid.	Intercept	Per capita Pork	Beef	Civilian consumption Broiler	Turkey
Model I-B-a	0.895	1.476	68.660	85.100	80.196	-2.1066**	-0.8837**	-1.1202**	0.9146**
T value[a]						(10.698)	(4.384)	(3.176)	(6.051)
I-A-a	0.9947	1.726	1294.5	75.855	72.5665	-2.0347**	-0.6615**	-1.2175**	0.7536**
						(10.143)	(3.105)	(3.455)	(5.224)
II-B-a	0.939	1.365	81.522	49.780	74.773	-2.1261**	-0.7264**	0.5965**	-0.1956**
						(12.908)	(3.875)	(1.335)	(0.284)
II-A-a	0.997	1.7304	1453.3	43.507	72.583	-1.9892**	-0.7270**	0.5762**	-0.0397**
						(11.525)	(3.591)	(1.241)	(0.060)
III-B-a	0.942	1.269	63.214	46.770	75.851	-2.1163**	-0.7556**	0.6573**	0.0571**
						(8.643)	(4.004)	(1.449)	(0.077)
III-A-a	0.997	1.630	1151.8	38.028	73.834	-2.0852**	-0.7152**	0.6553**	0.5495**
						(9.248)	(3.592)	(1.438)	(0.845)
Model I-B-b	0.912	1.258	24.56	2903.4	13.867	-2.0590**	-1.4178**	-0.5443**	0.0881**
						(12.997)	(6.106)	(4.427)	(6.689)
I-A-b	0.999	1.0708	34.16	2875.2	7.3737	-1.6295**	0.3396**	-0.4648**	0.0533**
						(8.555)	(1.756)	(3.113)	(3.509)
II-B-b	0.937	1.033	15.04	3390.7	13.562	-1.9727**	-1.4635**	0.0682**	0.0461**
						(13.186)	(6.567)	(0.385)	(0.573)
II-A-b	0.999	1.544	18.92	3342.1	12.554	-1.8204**	-1.2576**	0.1191**	0.1065**
						(11.802)	(5.329)	(0.704)	(1.663)
III-B-b	0.937	1.031	11.91	3045.0	13.542	-1.9749**	-1.4571**	0.0741**	0.0463**
						(8.769)	(6.299)	(0.397)	(0.550)
III-A-b	0.999	1.538	14.96	2927.9	12.668	-1.8823**	-1.2425**	0.1349**	0.1008**
						(9.395)	(5.097)	(0.765)	(1.503)

[a]The T values are shown directly beneath the coefficient. The asterisk designation, * and **, indicates significance at 5 and 1 percent levels of significance respectively. The sum of squared residuals for the nonlinear equations is calculated as discussed in Section D, page 35.

Table 2. (Continued)

	Margin farm wholesale	Time	Deviation of income	D_2	D_3	D_4	$C_p \cdot D_2$
Model I-B-a	-0.8012**	0.3478**	0.0171**				
	(4.198)	(8.038)	(10.429)				
I-A-a	-0.6076**	0.3210**	0.0158**				
	(2.798)	(7.151)	(8.725)				
II-B-a	-0.9359**	0.1973**	0.0175**	-2.9697**	-1.4626	2.6672	
	(5.919)	(3.536)	(12.923)	(4.999)	(1.574)	(1.236)	
II-A-a	-0.9369**	0.1976**	0.0174**	-2.8332**	-1.3986	2.0923	
	(5.020)	(3.482)	(11.339)	(4.811)	(1.510)	(1.009)	
III-B-a	-1.0074**	0.1984**	0.0179**	3.001	1.6983	-3.2865	-0.4030
	(6.114)	(3.482)	(13.009)	(0.413)	(0.257)	(0.475)	(0.866)
III-A-a	-0.9657**	0.1857**	0.0178**	0.2804	1.1086	-8.2794	-0.2282
	(5.384)	(3.305)	(11.636)	(0.048)	(0.188)	(1.504)	(0.603)
I-B-b	-0.3729**	0.3788**	1.9742**				
	(2.534)	(9.399)	(11.959)				
I-A-b	-0.3209	0.2166**	0.0009**				
	(1.648)	(4.800)	(6.708)				
II-B-b	-0.5023**	0.2183**	1.7915**	-0.1342**	-0.0761	0.0391	
	(3.459)	(3.761)	(10.148)	(3.403)	(0.985)	(0.282)	
II-A-b	-0.4962**	0.1731**	1.6323**	-0.1530**	-0.1335	-0.0753	
	(3.224)	(3.224)	(9.181)	(4.595)	(2.067)	(0.690)	
III-B-b	-0.5009**	0.2156**	1.7824**	0.1686	-0.2982	0.0828	-0.0559
	(3.229)	(3.524)	(9.607)	(0.016)	(0.308)	(0.099)	(0.143)
III-A-b	-0.4966**	0.1677**	1.6201**	-0.2296	-0.4147	-0.4150	0.0263
	(3.169)	(3.009)	(8.793)	(0.291)	(0.520)	(0.742)	(0.091)

Table 2. (Continued)

	$C_p \cdot D_3$	$C_p \cdot D_4$	$\hat{\rho}$
Model I-B-a			
I-A-a			0.2545* (2.044)
II-B-a			
II-A-a			0.2986* (2.4855)
III-B-a	-0.2305 (0.558)	0.2980 (0.878)	
III-A-a	-0.2210 (0.597)	0.4998 (1.912)	0.3437** (2.9015)
I-B-b			
I-A-b			0.3675** (3.0386)
II-B-b			
II-A-b			0.4715** (4.152)
III-B-b	0.0816 (0.234)	-0.0154 (0.053)	
III-A-b	0.1027 (0.353)	0.1238 (0.620)	0.4729** (4.1723)

Table 2. (Continued)

	R^2	Durbin-Watson	F-Ratio	SS Resid.	Inter-cept	Per capita Pork	Beef	Civilian consumption Broiler	Turkey
Model I-B-c	0.808	1.082	33.849	83.899	71.197	-1.8524** (9.493)	-0.7585** (3.239)	-0.8032** (2.268)	0.7540** (5.100)
I-A-c	0.993	1.554	936.47	66.521	62.8445	-1.7450** (9.2550)	-0.3485** (1.522)	-1.0354** (3.038)	0.5085** (3.834)
II-B-c	0.869	0.960	35.128	57.537	68.870	-1.8628** (10.267)	-0.6906** (2.819)	0.6041** (1.270)	-0.4399** (0.599)
II-A-c	0.995	1.696	972.41	41.909	69.0589	-1.6577** (9.5501)	-0.7056** (2.8703)	0.5783** (1.2186)	0.17603** (0.276)
III-B-c	0.874	0.898	26.644	55.364	71.192	-1.9413** (7.204)	-0.7038** (2.840)	0.5941** (1.425)	-0.1661** (0.208)
III-A-c	0.994	1.535	757.61	38.487	70.1834	-1.8388** (7.969)	-0.6347** (2.595)	(0.6330** (1.337)	0.7039** (1.052)
I-B-d	0.8501	1.085	20.75	1743.7	13.767	-1.8510** (12.243)	-1.4320** (4.968)	-0.3802** (3.171)	0.0839** (6.068)
I-A-d	0.999	1.477	37.48	1662.4	11.7089	-1.8230** (11.533)	-0.7937** (2.883)	-0.4757** (3.953)	0.0650** (5.953)
II-B-d	0.903	1.0136	12.76	1606.6	13.715	-1.8592** (13.335)	-1.4891** (5.306)	0.2031** (1.316)	0.0083** (0.1006)
II-A-d	0.999	1.582	15.07	1536.7	12.544	-1.7876** (11.865)	-1.1628** (4.020)	0.1611** (0.998)	0.0911** (1.424)
III-B-d	0.903	1.006	19.30	1492.1	13.980	-1.9560** (8.725)	-1.4815** (5.112)	0.2106** (1.319)	0.0150** (0.175)
III-A-d	0.999	1.550	22.96	1417.3	12.785	-1.8930** (9.525)	-1.1436** (3.862)	0.1683** (1.004)	0.0881** (1.329)

Table 2. (Continued)

	Margin farm wholesale	Time	Deviation of income	D_2	D_3	D_4	$C_p \cdot D_2$
Model I-B-c	-0.5173*	0.1503**	0.0207**				
	(2.279)	(3.487)	(5.939)				
I-A-c	-0.5099*	0.1138*	0.0162**				
	(2.374)	(2.636)	(4.194)				
II-B-c	-0.6801**	0.0286	0.0220**	-2.4174**	-0.8663	3.0748	
	(3.305)	(0.469)	(6.778)	(3.787)	(0.859)	(1.329)	
II-A-c	-0.8830**	0.0135	0.0226**	-2.4162**	-1.1489	1.0368	
	(4.532)	(0.240)	(6.144)	(4.057)	(1.246)	(0.518)	
III-B-c	-0.7548**	0.0171	0.0224**	1.3244	-2.5395	-3.9162	-0.2653
	(3.503)	(0.272)	(6.793)	(0.167)	(0.356)	(0.524)	(0.524)
III-A-c	-0.8728**	-0.0071	0.0219**	-3.2257	-3.1670	-8.2271	0.0275
	(4.551)	(0.126)	(5.984)	(0.576)	(0.549)	(1.611)	(0.076)
I-B-d	-0.4707**	0.1983**	2.2166**				
	(3.005)	(4.995)	(7.300)				
I-A-d	-0.3796*	0.1691**	1.6937**				
	(2.496)	(4.046)	(5.236)				
II-B-d	-0.5761**	0.0423	1.9083**	-0.1357**	-0.0529	0.0997	
	(3.999)	(0.775)	(5.974)	(3.383)	(0.642)	(0.694)	
II-A-d	-0.5165**	0.0100	1.5706**	-0.1518**	-0.1259	-0.0495	
	(3.478)	(0.188)	(4.813)	(4.437)	(1.872)	(0.451)	
III-B-d	-0.5805**	0.0369	1.8852**	-0.3579	-0.6573	-0.2699	0.0779
	(3.816)	(0.653)	(5.696)	(0.331)	(0.684)	(0.324)	(0.198)
III-A-d	-0.5190**	0.0055	1.5498**	-0.6267	-0.5634	-0.5302	0.1718
	(3.420)	(0.099)	(4.637)	(0.746)	(0.705)	(0.951)	(0.595)

Table 2. (Continued)

	$C_p \cdot D_3$	$C_p \cdot D_4$	$\hat{\rho}$
Model I-B-c			
I-A-c			0.4439** (3.925)
II-B-c			
II-A-c			0.4830** (4.442)
III-B-c	0.0805 (0.181)	0.3589 (0.979)	
III-A-c	0.0769 (0.210)	0.4508 (1.888)	0.5094** (4.844)
I-B-d			
I-A-d			0.4569** (4.0143)
II-B-d			
II-A-d			0.4863** (4.3575)
III-B-d	0.2177 (0.631)	0.1276 (0.444)	
III-A-d	0.1587 (0.544)	0.1727 (0.867)	0.4907** (4.4033)

variable of turkey, results in reducing R^2 from 0.895 for Group a and 0.808 for Group c (as indicated in the table) to 0.830 and 0.72 respectively. The coefficient of the per capita consumption of broiler variable altered in sign from negative to positive, moving from Model I to Model II (i.e., after adding dummy variables to allow a change in intercept between quarters). Thus introducing the dummy variables results in changing the classification of broiler as complementary instead of competitive to pork. Also, the sign of the coefficient for per capita consumption of turkey was altered from positive to negative between Model I and II respectively. However, after transformation using the deflated variables in linear and nonlinear forms, the coefficient remains with a positive sign (i.e., complementary). The alteration of sign could result from the significant income effect or perhaps because of the high intercorrelation between consumption of turkey variable and D_4, and time trend which were 0.93 and 0.94 respectively. Also high intercorrelation of 0.94 was observed between the consumption of broiler variable and time trend. However, the theoretical expectations about the signs of the regression coefficient cannot be strongly imposed on the inverse coefficient matrix that results from using prices as the dependent variables in fitting the demand equations.

The deviation of income and time trend variables were significant at 5 and 1 percent level in all the equations. The per capita consumption of pork variable has a highly significant coefficient at the 5 and 1 percent levels with the expected negative sign throughout. The same can be said about the coefficient for the per capita consumption of beef variable, except for equations I-A-b and I-A-c where the negative coefficient was not significant. The coefficient of the farm wholesale margin of pork variable, having the expected negative sign, is significant at 5 percent level in all equations. The equations under Group a (i.e., linear - current dollars) have higher R^2 values than those under Group c (i.e., linear - deflated). However, according to the microeconomic theory where the demand is said to be homogeneous of degree zero in prices and income, the deflated equations are more reasonable. On the other hand, the deflation procedure may be unnecessary when the objective of the analysis is to forecast price.

The Durbin-Watson statistic is low for all fitted equations using original variables (i.e., before transformation or Group B). The hypothesis of random residuals was rejected, and the original variables were transformed by means of $\hat{\rho}$ coefficients which were significant at the 5 percent level throughout. This transformation procedure results in increasing D-W statistic up to the inconclusive range. However, transforming equation I-B-b results in lower D-W value which may be caused by incorrect specification of the relationship between the successive disturbances (i.e., assume first order but the actual relationship may be second order).

The dummy variables added in Model II indicate a significance deviation in the intercept for quarters two, three and four from quarter one. The intercept coefficients for the four quarters from equation II-A-a were:

First quarter intercept coefficient = 72.583

Second quarter intercept coefficient = 69.750

Third quarter intercept coefficient = 71.184

Fourth quarter intercept coefficient = 74.675.

They are in decreasing order starting from quarter four, one, three and two. Using Model II-A-c also results in the same order as follows:

First quarter intercept coefficient = 69.059

Second quarter intercept coefficient = 66.643

Third quarter intercept coefficient = 67.910

Fourth quarter intercept coefficient = 70.096.

In Model III, where the slopes are allowed to change between quarters, no significant deviation was observed in the slope in quarters two, three and four from quarter one. However, the slope of the demand seems to be flatter in the second and third quarters than in the first and fourth quarters. Some of the dummy variables used in Models II and III are not significant by themselves, but the question of whether they add more significance or accuracy to the fit still needs more investigation.

The transformed equations for the models (i.e., Group A) were considered, and Model I was tested against Model II using the F-test of homogeneity. The hypothesis of no change in intercept level between quarters (i.e., Model II is not an improvement over Model I) was rejected at both 5 and 1 percent levels. The calculated F-value using models under Group a is 12.886, which is greater than the F-table values of 2.78 and 4.18 for 5 and 1 percent significance respectively with 3 and 52 degrees of freedom. The same test is performed for the models of Group c and the calculated F-value is 10.179 which is also significant at the 5 and 1 percent levels for the same degrees of freedom. Thus, the hypothesis is rejected using equations with nominal and deflated variables.

Models II and III were compared, using F-test of homogeneity to test the hypothesis of no change in slopes between quarters (i.e., Model III is not an improvement over Model II). The calculated F-value obtained from using the models under Group a is 2.352, which is smaller than the F-table values of 2.80 and 4.20 at 5 and 1 percent respectively, for 3 and 49 degrees of freedom. Thus the test failed to reject the hypothesis. The same test was performed using models under Group c; the resultant calculated F-value is 1.451 which is nonsignificant at 1 or 5 percent level for the same degrees of freedom. The results again failed to reject the hypothesis.

The results obtained from the same tests applied to the logarithmic equations also reject the hypothesis of no difference in quarterly intercept values and failed to reject the second hypothesis of no difference between quarters in the slope of the demand curve. Thus, the linear and nonlinear forms using nominal or deflated variables agree in indicating Model II to be the best model for this stage.

C. The Effect of Change in the Level of Supply

In order to examine the accuracy of Model II more closely, the per capita consumption of pork variable is examined to see whether differences in the supply level affect the quantitative characteristics of the price-quantity relationship of hogs. The data on per capita consumption of pork is classified to high, medium and low levels, based on whether the observation is greater or smaller than specific range around the mean value for each quarter for the sample period. The calculated mean values were 16.3, 15.2, 14.9 and 17.5 for the first, second, third and fourth quarter respectively. The range for the values considered as medium level for the first, second, third and fourth quarter are 16.2 to 16.6, 15.0 to 15.6, 14.5 to 15.2 and 17.0 to 17.9 respectively. The high and low levels for each quarter are those values greater or smaller than its corresponding range.

Model II (i.e., including its four equations) was shown to be the best model from the first stage of analysis. Two dummy variables are added to that model to allow changes in intercept level between high, medium and low levels of supply (i.e., Model IV). In Model V allowance is made for change in the slope between high, medium and low level of supply. Each model is fitted four times as before (i.e., a-b-c and d), where only the transformed variables were used (i.e., Group A).

Table 3 presents the resultant regression coefficients of each fit, their T-values and significance at 5 and 1 percent levels. Also presented in the table are the various measures of fit of the equations (i.e., coefficient of multiple determination, R^2, F-test of overall significance of the variables, and sum of squared residuals). The Durbin-Watson statistics are presented for each fit along with the $\hat{\rho}$ coefficient and its level of significance at the 5 and 1 percent levels.

Adding these dummy variables did not effect the value of R^2. Individually none of them are significant at 5 or 1 percent level except H in IV-A-a and IV-A-c which is significant at the five percent level. The

Table 3. Estimated coefficients for Models IV and V

	R^2	Durbin-Watson	F Ratio	SS Residuals	Inter-cept	Per capita civilian consumption Pork	Beef	Broiler
Model IV-A-a	0.9967	1.7784	1164.6	38.429	71.6655	-2.2119** (7.899)	-0.6017** (2.971)	0.5093 (1.122)
V-A-a	0.9965	1.6870	916.23	36.936	65.8102	-2.2423** (6.346)	-0.3974 (1.982)	0.6591 (1.426)
IV-A-b	0.9995	1.6059	11.78	3810.2	11.8823	-1.7741** (7.917)	-1.1121** (4.604)	0.0986 (0.607)
V-A-b	0.9995	1.5992	22.70	953.4	12.0153	-1.7971** (6.246)	-1.1421** (4.540)	0.1085 (0.640)
IV-A-c	0.9936	1.7081	593.34	36.345	67.1149	-1.8699** (6.841)	-0.5539* (2.231)	0.2729 (0.591)
V-A-c	0.9935	1.6827	487.75	32.638	66.6874	-1.8611** (5.872)	-0.5297* (2.098)	0.3007 (0.667)
IV-A-d	0.9995	1.6134	11.58	2920.8	12.0889	-1.7944** (8.109)	-1.0457** (3.533)	0.1218 (0.781)
V-A-d	0.9995	1.5996	25.51	638.7	12.0951	-1.7875** (6.312)	-1.0559** (3.386)	0.1286 (0.789)

* and ** indicating significance at 5 and 1 percent level respectively.

Table 3. (Continued)

	Turkey	Margin farm wholesale	Time	Deviation of income	D_2	D_3	D_4
Model IV-A-a	-0.1934	-0.7966**	0.1803**	0.0162**	-2.7522**	-1.4765	2.7503
	(0.308)	(4.259)	(3.279)	(10.148)	(4.212)	(1.609)	(1.355)
V-A-a	0.4412	-0.7578**	0.1189*	0.0155**	-3.1927**	-2.6211*	0.5701
	(0.718)	(4.032)	(2.377)	(9.573)	(4.387)	(2.477)	(0.264)
IV-A-b	0.0729	-0.4609**	0.1717**	1.5496**	-0.1300**	-0.0996	-0.0223
	(1.062)	(3.045)	(3.335)	(8.731)	(3.736)	(1.505)	(0.187)
V-A-b	0.0707	-0.4601**	0.1724**	1.5664**	-0.1304**	-0.0981	-0.0187
	(0.997)	(2.943)	(3.253)	(8.519)	(3.609)	(1.435)	(0.151)
IV-A-c	0.0160	-0.6781**	0.0276	0.0194**	-2.0771**	-0.9729	1.7187
	(0.027)	(3.345)	(0.522)	(4.804)	(3.263)	(1.106)	(0.903)
V-A-c	0.1344	-0.7022**	0.0217	0.0189**	-2.1316**	-1.1478	1.3865
	(0.221)	(3.585)	(0.418)	(4.560)	(3.420)	(1.319)	(0.708)
IV-A-d	00.0568	-0.4745**	0.0203	1.4979**	-0.1289**	-0.0918	0.0086
	(0.817)	(3.181)	(0.396)	(4.496)	(3.613)	(1.331)	(0.071)
V-A-d	0.0550	-0.4762**	0.0196	1.5051**	-0.1289**	-0.0904	0.0115
	(0.768)	(3.099)	(0.369)	(4.313)	(3.495)	(1.277)	(0.092)

Table 3. (Continued)

	H	L	$H \cdot C_p$	$L \cdot C_p$	$\hat{\rho}$
Model IV-A-a	0.8663* (2.461)	0.3792 (0.905)			0.2849* (2.3431)
V-A-a	-4.8013 (0.923)	5.2662 (1.177)	0.3393 (1.068)	-0.3216 (1.132)	0.3196* (2.638)
IV-A-b	0.0173 (0.997)	0.0261 (1.296)			0.4006** (3.372)
V-A-b	-0.1247 (0.179)	-0.0264 (0.044)	0.0508 (0.204)	0.0195 (0.089)	0.3784** (3.164)
IV-A-c	0.6695* (2.010)	0.3450 (0.871)			0.4638** (4.223)
V-A-c	-2.8617 (0.598)	4.6286 (1.123)	0.2068 (0.709)	-0.2797 (1.069)	0.4968** (4.679)
IV-A-d	0.0208 (1.182)	0.0224 (1.095)			0.4000** (3.392)
V-A-d	0.0144 (0.020)	0.0466 (0.076)	0.0023 (0.009)	-0.0085 (0.038)	0.3883** (3.283)

regression coefficients and the various statistical measurements presented in the table are results of fitting the transformed variables which in turn were used because of a significant $\hat{\rho}$ coefficient.

The regression coefficients of the consumption variables for pork and beef are significant at the five and one percent levels and have the expected negative sign throughout except in Model IV-A-a where the regression coefficient of the beef consumption variable is not significant. The regression coefficient of the consumption variables for broiler and turkey are not significant at either level, and have positive sign -- which again tends to explain them as complementary goods for pork. This unexpected sign may come about because of the same reasons discussed in Section B, page 44. The regression coefficients for farm wholesale margin of pork and the deviation of income variables are significant at the 5 and 1 percent levels with the expected negative and positive signs respectively. The transformation process improved the Durbin-Watson statistics, but the test is poor in this stage since the number of variables used in the models are relatively large compared to the available number of variables in the published D-W tables.

Two hypotheses are tested, the first that there is no change in the intercept level between high, medium and low levels of pork supply (i.e., Model IV is not an improvement over Model II). Model II was tested against Model IV using the F-test for homogeneity. The calculated F-value using Models II and IV under Group a is 3.302 which is greater than 3.18, the table F-values at the five percent level, for 2 and 50 degrees of freedom. The same test was performed using models under Group c, and the calculated

F-value of 3.827 was significant at the five percent level for the same degrees of freedom. The results of the test reject the hypothesis which means that Model IV is an improvement over Model II and there is evidence that the level of pork supply (comparing high, medium and low levels) affects the relationship between a change in supply and the price of hogs.

The F-test for homogeneity is performed again using logarithmic equations (i.e., Groups b and d) to test the same hypothesis. The results from using the logarithmic equation supported the results obtained from their counterpart linear equation and reject the hypothesis.

The second hypothesis is that there is no change in the slope at high, medium and low supply levels. Models IV and V are compared to test this hypothesis. Using the models under Group a, the calculated F-value of 0.970 is not significant at the 5 or 1 percent levels (i.e., smaller than 3.19 and 5.08 respectively) for 2 and 48 d.f. The calculated F-value from using the models under Group c is 2.726 which is again not significant at the 5 or 1 percent levels for the same degrees of freedom. Thus the results of the tests failed to reject the hypothesis of no change in the slope between high, medium and low levels of supply. The results obtained from using the logarithmic equations also failed to reject the hypothesis. Thus, again the linear and nonlinear forms using variables measured in current dollars or deflated agree in indicating that Model IV is the more adequate model.

The results obtained from testing the null hypothesis concerning the effect of the different levels of pork supply are consistent with those obtained from testing the null hypothesis concerning the effect of seasonal variation in explaining the price-quantity relationship for live hogs.

The dummy variables added in Model IV indicate a significant deviation in the intercept for high and low level from the medium level for each quarter. The intercept coefficient for the four quarters from Model IV-A-a are

First quarter intercept coefficient, high = 72.5318

First quarter intercept coefficient, medium = 71.6655

First quarter intercept coefficient, low = 72.0447

Second quarter intercept coefficient, high = 69.7796

Second quarter intercept coefficient, medium = 68.9133

Second quarter intercept coefficient, low = 69.2925

Third quarter intercept coefficient, high = 71.0553

Third quarter intercept coefficient, medium = 70.1890

Third quarter intercept coefficient, low = 70.4345

Fourth quarter intercept coefficient, high = 75.2821

Fourth quarter intercept coefficient, medium = 74.4158

Fourth quarter intercept coefficient, low = 74.7950.

D. Direct and Cross Price Flexibilities

Model IV is considered to be superior over all the other models in explaining the price-quantity relationship for hogs at the primary market level. This section is concerned with examining the direct and cross price flexibilities obtained from this selected model. Table 4 shows the direct and cross price flexibilities obtained from the logarithmic forms (i.e., nominal and deflated).

Table 4. Price flexibilities from log equations

Models	Effect on price of hogs of a 1-percent change in per capita consumption of: Pork	Beef	Broiler	Turkey	Deviation of income effect on prices
IV-b-p_p	-1.7741	-1.1121	0.0986	0.0729	1.5496
IV-d-p_p	-1.7944	-1.0457	0.1218	0.0568	1.4979

These flexibilities are considered as intermediate range price flexibilities. The direct price flexibility for pork explains the percentage change in the price of live hogs due to 1 percent change in the per capita consumption of pork. The direct price flexibilities are negative as expected. The cross price flexibilities for broiler and turkey have unexpected positive sign, where it indicates complementarity between broiler, turkey and pork. Again this unexpected positive sign raises a question about the validity of such computation and questions about the presence of the high correlation between consumption of turkey and D_4, between consumption of broiler and time and using the prices as the dependent variable where the theoretical expectations about the regression coefficient sign cannot impose strongly upon the inverse matrix of regression coefficient.

The income flexibility, which explains the effect of income on prices, is of great interest. One method to obtain this kind of information is by including the actual income variable in the selected equations instead of the deviation of income variable (3, p. 87). However, since the superior fit obtained from the study included the deviation of income variable, the effect of the deviation from income on prices is presented in Table 4. The interpretation and validity of this value needs more investigation. This flexibility represents the percentage change in prices of live hogs due to a one percent change in the portion of income that is not explained by time trend. Since the deviation of income variable has an economic meaning and usefulness in price analysis, the flexibility obtained from such variable has to be considered more closely by the economists concerned. On the other hand, it should be clear that this flexibility is not similar to the income flexibility since the deviation of income variable contains positive and negative observations and it is not similar to the straight income variable in any respect. But since the use of income and time trend will result in high inter-correlation and since omitting the time trend variable from the selected models will effect the magnitude of the regression coefficients of the models, thus, the use of the effect of income deviation on prices with the correct interpretations is more reasonable.

Since Model II indicated a significant shift in the intercept level of the demand curve between quarters, the price flexibilities are also expected to vary between quarters. In Table 5, the direct price flexibilities calculated from the linear equations of Model II are compared to those obtained from the logarithmic equations of Model III. The fourth quarter has the highest direct price flexibility as calculated from both equations of Model II with the same decreasing order. The next higher price flexibility is for the first quarter, followed by flexibilities for the second and third quarters in that order.

Table 5. Direct price flexibilities for live hogs by quarters

Model	Effect of 1% change in per capita consumption of pork on prices of live hogs			
	1st quarter	2nd quarter	3rd quarter	4th quarter
II-A-a	-1.768	-1.623	-1.501	-1.989
III-A-b	-1.8823	-1.8560	-1.7796	-1.7585
II-A-c	-1.618	-1.464	-1.366	-1.822
III-A-d	-1.8930	-1.7212	-1.7342	-1.7203

Using the logarithmic equations of Model III, the first quarter has the highest direct price flexibility in both fits, but the decreasing order differ. Using equation III-A-b, the second quarter's flexibility is the next higher, then the third and fourth quarters. The results of equation III-A-d indicated that the third quarter has the next higher flexibility, followed by the third and fourth quarters. So, the order of second and third quarters differ slightly from fitting the logarithmic equation of Model III with nominal and deflated variables.

Since the results of testing the third hypothesis indicated a significant change in the intercept level of the demand curve for the different levels of pork consumption (i.e., Model IV is an improvement over Model II), the price flexibilities relevant to the different levels are expected to differ. Testing the fourth hypothesis indicated that Model V is not an improvement over Model IV. The direct hog price flexibilities relevant to high, medium and low level of per capita consumption of pork obtained from nominal and deflated fits of Model IV and V are presented in

Table 6.

Table 6. Direct price flexibilities for live hogs at different per capita pork consumption levels

Model	Effect of 1% change in per capita consumption of pork on the prices of live hogs at different levels of consumption High	Medium	Low
IV-a	-1.951	-2.034	-1.901
V-b	-1.7463	-1.7971	-1.7776
IV-c	-1.832	-1.853	-1.624
V-d	-1.7852	-1.7875	-1.7960

The direct price flexibilities associated with the medium level of per capita consumption of pork, as calculated from the linear equations of Model IV, one the highest and both have the same decreasing order. The price flexibilities associated with the high level of consumption are the next in magnitude, then those at the low level of consumption. The price flexibilities obtained from the logarithmic equations of Model V differ in magnitude and order from those calculated from the linear equations of Model IV. The results obtained from equation V-b indicated that the price flexibility associated with the medium level is the highest, followed by those associated with the low and high levels respectively. Equation V-d yields the highest direct price flexibility at the low level of consumption, followed by the flexibilities at the medium and high levels respectively.

The direct price flexibilities calculated from the linear equations of Model IV may appear to be more reasonable, since Model IV is the most acceptable model in explaining the price-quantity demand relationship for live hogs in the primary market. These flexibilities, as estimated for different levels of per capita pork consumption, show relatively small changes within models, except for the flexibility for the low level of supply under Model IV-c.

E. Using Model IV in Forecasting

The sample period under study includes 64 calendar quarters starting from the first quarter of 1955 through the fourth quarter of 1970. An attempt is made to test the accuracy of the model in predicting live hog prices for the four quarters of 1971 and the first two quarters of 1972. The predicted prices were compared against the actual available prices for that period. Equation (9) was used to estimate the predicted prices. Table 7 presents the actual prices for that period, the predicted prices using Model VI-a (i.e., linear-nominal), the absolute difference between them and the percentage difference (i.e., $\frac{P_{pi} - \hat{P}_{pi}}{P_{pi}} \times 100$).

The actual prices are computed as the simple average of weekly prices for the period. The differences for all the six equations are negative which shows that the predicted prices are consistently higher than the actual prices.

More considerations need to be given to the procedure for introducing the deviation of income variable to the prediction equation. The method used here was to obtain this variable by regressing the per capita income variable on the time trend using the seventy quarters together. Then the

Table 7. Forecasted live hog prices using Model IV-a

Quarters	Actual prices (p_{pi}) (\$/100 wts.)	Predicted prices ($\hat{p}_{pi}$) (\$/100 wts.)	Difference ($p-\hat{p}$) (\$/100 wts.)	% Percentage differences
First quarter 1971	17.43	19.68	-2.25	-12.94%
Second quarter 1971	17.22	18.68	-1.46	- 8.47%
Third quarter 1971	18.95	19.86	-0.91	- 4.82%
Fourth quarter 1971	19.88	21.21	-1.33	- 6.70%
First quarter 1972	24.48	24.87	-0.39	- 1.57%
Second quarter 1972	24.83	25.64	-0.81	- 3.25%

last six observations were picked and used in the prediction equation. As an alternative, the deviation of income observations for the six quarters under consideration were obtained following the same relationship between the income and time trend variables observed during the sample period. However, the absolute and percentage differences between actual prices and predicted prices are higher under this method.

VI. SUMMARY, CONCLUSION AND SUGGESTIONS FOR FURTHER STUDIES

A. Summary and Conclusion

The study is concerned with estimating the price-quantity relationship for live hogs in the primary market in order to approach reasonably accurate forecasts of prices, given reliable estimates of specified relevant variables. The estimation was done by using quarterly time series data from the first quarter of 1955 through the fourth quarter of 1970. Five models were constructed to explain this relationship. In the first model no allowance is made for any change in intercept or slopes between quarters. In the second model allowance is made for the intercept to change between quarters. The third model is introduced with allowance for both the intercept and slope to change between quarters. In Model four, allowance is made for a change in the intercept between high, medium and low levels of pork supply for each quarter. Finally, in Model five, the intercept and slope are allowed to change between the high, medium and low levels of pork supply. Each model is represented by four fits. Two of them use variables measured in current dollars for both linear and non-linear forms. The other two use deflated variables in both linear and nonlinear forms. Since the per capita disposable income and time trend variables are highly correlated, the deviation of income from trend is introduced as a variable to the models along with the time trend variable. The hypothesis of random residuals is rejected at the one percent level using the Durbin-Watson statistic. The original variables are transformed using autoregression least square method to reduce the autocorrelation between the successive disturbances of the time series data using one alteration.

The models with transformed variables are considered, and four hypotheses were tested using the F-test of homogeneity between different models. The results of these tests indicate empirical evidence of seasonal variation in the level of demand between the calendar quarters of the year. However, there is no empirical evidence of significant change in the slope of the demand relationship between quarters. The results of these tests also provide an empirical evidence of the effect of high and low levels of pork supply on the level of the demand curve. Thus Model IV (where allowance is made for a change in the intercept level between quarters and between high, medium and low level of per capita pork consumption) is considered to be of superior fit over all the other models in explaining the price-quantity relationship of live hogs. The four equations that used to represent Model IV are of equivalent accuracy in explaining such relationship.

Adding the dummy variables in Model II results in positive regression coefficients for the per capita consumption of broiler and turkey variables. These unexpected positive signs classify broiler and turkey as complementary goods with pork. However, the high income effect and the high intercorrelation between per capita consumption of turkey and the dummy variable for fourth quarter (i.e., D_4), along with the high intercorrelation between per capita consumption of broiler and time trend variable that is presented in the model, are partially responsible for the alteration of the regression coefficient sign for those consumption variables. Also, using the prices as the dependent variable in all equations prevent imposing the theoretical expectations upon the inverse regression coefficient matrix. The same reasons caused the cross price flexibility for the consumption variables of broiler and turkey to be positive. The direct price flexibility for pork is highly reasonable compared to the results obtained for other studies. Also, the effect of deviation of income on prices of hogs is introduced in the study instead of the income flexibility.

The accuracy of using Model IV in forecasting live hogs prices in the primary market was tested. Equation IV-A-a (i.e., Model IV using variables measured in current dollars after transformation - linear form) was used to forecast the prices for the four quarters of 1971 and the first and second quarters of 1972. The predicted prices are higher than the observed actual prices for the six quarters. The absolute difference between actual and predicted prices ranged from -0.39 to -2.25 dollars and the percentage differences ranged from 1.57 to 12.94 percent for the forecast period.

B. Suggestions for Further Studies

The procedure to reduce the autocorrelation between the successive disturbances of the quarterly time series data used in the study is based on the assumption that first order autoregressive scheme exists between the disturbances term. However, eliminating the existence of autocorrelation may require using more complicated procedures based on the assumption of the existence of second or higher order scheme. Some of the procedures are discussed by Johnston (16) and Thiel (34).

This study is mainly devoted to estimating the price-quantity relationship of live hogs at the primary market. The models used to explain this relationship are fitted twice, using variables measured in current dollars and the same variables are deflated by the Consumer Price Index. The same procedures could be used to estimate the price-quantity relationship for other livestock, and using variables deflated by the wholesale-price index could be considered for the same models.

VII. BIBLIOGRAPHY

1. Barton, A. P. Estimating demand equations. Econometrica 36: 213-215. April 1968.

2. Breimyer, Harold F. On price determination and aggregate price theory. JFE 39: 676-694. 1957.

3. Buttimer, Andreas. Quarterly fluctuation in meat demand functions. Unpublished M.S. thesis. Library, Iowa State University of Science and Technology, Ames, Iowa. 1968.

4. Draper, N. and Smith, H. Applied regression analysis. John Wiley and Sons, Inc., New York. 1966.

5. Durbin, J. and Watson, G. S. Testing for serial correlation in least squares regression. Biometrica 37: 409-428. 1950.

6. Ferguson, G. E. Microeconomic Theory. Richard D. Irwin, Inc., Homewood, Illinois. 1969.

7. Foote, Richard J. Analytical tools for studying demand and price structures. United States Department of Agriculture, Agricultural Handbook No. 146. Aug. 1958.

8. Foote, Richard J. and Fox, Karl A. Analytical Tools for Measuring Demand. United States Department of Agriculture, Agricultural Marketing Service, Agricultural Handbook No. 64. Jan. 1954.

9. Fox, Karl A. The analysis of demand for farm products. United States Department of Agriculture, USDA Bulletin 1081. 1953.

10. Fox, Karl A. Factors affecting the accuracy of price forecasts. JFE 35, No. 3: 323-340. August 1953.

11. Goldberger, A. S. Econometric theory. John Wiley and Sons, Inc., New York. 1964.

12. Goldberger, A. S. Best linear unbiased prediction in the generalized linear regression model. Journal of the American Statistical Association 57: 369-375. June 1962.

13. Graybill, Franklin A. An introduction to linear statistical models. Vol. 1. McGraw-Hill, New York. 1961.

14. Henderson, James M. and Quant, Richard E. Microeconomic Theory, A Mathematical Approach. Second edition. McGraw-Hill, Inc., New York. 1971.

15. Hood, W. C. and Koopmans, T. C. Studies in Econometric Method. Cowles Commission, Wiley and Sons, Inc., New York. 1953.

16. Johnston, J. Econometric Methods. McGraw-Hill Book Company, New York. 1960.

17. Houck, James P. A look at flexibilities and elasticities. JFE 48: 225-234. 1966.

18. Karg, G. Quarterly marketing margin equations for pork, beef and lamb. Unpublished M.S. thesis. Library, Iowa State University of Science and Technology, Ames, Iowa. 1969.

19. Kuhlman, J. M. and Thompson, R. G. Substitution and value of elasticities. American Economic Review 55: 506-510. 1965.

20. Ladd, George W. Regression analysis of seasonal data. Journal of the American Statistical Association 59: 402-421. June 1964.

21. Ladd, George W. Experiments with autoregressive error estimation. Iowa Agricultural Experiment Station Research Bulletin 533. 1965.

22. Ladd, George W. and Martin, James E. Applications of distributed lag autocorrelated error models to short run demand analysis. Iowa Agricultural Experiment Station Research Bulletin 526. 1964.

23. Logan, Samuel H. and Boles, James N. Quarterly fluctuation in retail prices of meats. JFE 44: 1050-1060. 1962.

24. McIntosh, C. E. and Hawkins, M. H. Dummy variables: An application in cattle price analysis. Canadian Journal of Agricultural Economics 19(1): 47-54. July 1971.

25. Mellor, John W. The Economics of Agricultural Development. Cornell University Press, New York. 1970.

26. Mills, Frederick C. Statistical methods - applied to economic and business. Henry Holt and Co., New York. 1924.

27. Purcell, Joseph P. Livestock prices and meat supplies, trend and interrelation. Georgia Agricultural Experiment Station Technical Bulletin N.S. 24. May 1961.

28. Shepherd, Geoffrey S. Agricultural Price Analysis. Sixth edition. Iowa State University Press, Ames, Iowa. 1968.

29. Snedecor, G. W. and Cochran, W. G. Statistical methods. Sixth edition. Iowa State University, University Press, Ames, Iowa. 1971.

30. Solieman, M. A. Dummy variables and statistical efficiency of the estimators. Dept. of Agricultural Economics, University of Minnesota, Minneapolis, Minn. April 1969.

31. Staton, B. F. Seasonal demand for beef, pork and broilers. Agricultural Economics Research 13, No. 1: 1-14. 1961.

32. Stekler, H. O. Forecasting with econometric models: An evaluation. Econometrica 36: 437-463. 1968.

33. Stone, Richard. Measurement of consumer expenditure and behavior in the United Kingdom, 1920-1938. Cambridge University Press, Cambridge, England.

34. Theil, Henri. Principle of econometric. John Wiley and Sons, Inc., New York. 1971.

35. Tomek, W. G. and Cochrane, W. W. Long run demand: A concept and elasticity estimate for meats. JFE 44, No. 3: 717-731. 1962.

36. United States Department of Agriculture, Economic Research Service. Food consumption, price and expenditure. Agricultural Economic Report No. 138. July 1968.

37. United States Department of Agriculture, Economic Research Service. Economic and Statistical Analysis Division. Working data for demand analysis, Revision of Oct. 1970.

38. United States Department of Agriculture, Economic Research Service. Food consumption, price and expenditure. Supplement to Agric. Econ. Report No. 138, Supplement for 1970. Nov. 1971.

39. United States Department of Agriculture, Economic Research Service. Price spreads for beef and pork, revised series 1949-1969. U.S.D.A. Miscellaneous Publication No. 1174. May 1970.

40. United States Department of Agriculture, Economic Research Service. United States food consumption. U.S.D.A. Statistical Report No. 364. June 1965.

41. United States Department of Agriculture, Livestock Division, Agricultural Marketing Service. Market news, market review and statistics. Volume 23 through 26. 1955 through 1970.

42. United States Department of Agriculture, Livestock Division, Consumer and Marketing Service. Livestock, meat and wool market news. Volume 27 through 38. 1955 through 1970.

43. United States Department of Commerce. Social and Economic Statistics Administration, Bureau of Economic Analysis. Survey of Current Business Vol. 1-12. 1955 through 1970.

44. Waugh, Frederick V. Demand and price analysis - some examples from agriculture. United States Department of Agriculture, Economic and Statistical Analysis Division. USDA Tech. Bulletin No. 1316. Nov. 1964.

45. Wold, Herman. Demand analysis. John Wiley and Sons, Inc., New York, New York. 1953.

46. Working, Elmer J. Demand for meat. University of Illinois, University Press, Urbana, Illinois. 1954.

47. Working, Elmer J. What do "statistical demand curves" show. Quarterly Journal of Economics 41: 212-235. 1927.

VIII. ACKNOWLEDGMENTS

The author wishes to express sincere gratitude and thanks to his major professor, Dr. Gene Futrell, who provided valuable advice and guidance throughout the study and the graduate program. Without Dr. Futrell's help and guidance it would be impossible for the author to achieve his academic objectives. Thanks are also addressed to Dr. Ronald Raikes and Dr. David F. Cox who served on the author's graduate committee.

A word of thanks is addressed to Professor Herb Howell who helped and encouraged the author in the early stages of his graduate program. Thanks are also in order to Mrs. Carolyn Hartzler for typing the manuscript; Mrs. Doris Love for helping in completing other related tasks and to the author's family in Cairo, Egypt for their encouragement and concern.

Finally, the author wishes to express his deepest gratitude to his wife, Yousria, who provided the family environment and all possible willing assistance necessary to complete the study.

IX. APPENDIX

Table 8. Original data series used in the analysis

		A Price of live hogs, Omaha ($/100 wt.)	B Pork Farm wholesale margin (cents)	C Disposable income Per capita (dollars)	D Consumer price index 57-59 = 100
1955	1	16.21	14.8	1620.0	93.1
	2	17.66	13.5	1653.0	93.1
	3	16.82	15.0	1683.0	93.5
	4	12.18	16.3	1701.0	93.5
1956	1	12.47	15.6	1713.0	93.4
	2	15.96	13.7	1731.0	93.8
	3	16.58	15.0	1746.0	95.3
	4	15.58	14.1	1775.0	95.1
1957	1	17.46	14.7	1785.0	96.5
	2	18.63	14.8	1799.0	97.6
	3	20.50	15.8	1815.0	98.6
	4	17.36	15.1	1807.0	98.0
1958	1	20.18	15.6	1804.0	100.0
	2	21.66	14.9	1810.0	100.7
	3	21.63	15.6	1844.0	100.9
	4	18.08	16.0	1864.0	101.3
1959	1	15.97	16.0	1882.0	100.8
	2	15.82	16.0	1912.0	101.2
	3	14.40	17.1	1904.0	101.8
	4	12.49	17.4	1919.0	101.8
1960	1	13.95	16.0	1929.0	102.3
	2	16.19	15.5	1943.0	103.0
	3	17.12	15.6	1944.0	103.2
	4	17.21	14.9	1932.0	103.8
1961	1	17.66	14.8	1942.0	103.9
	2	16.59	14.4	1966.0	103.9
	3	18.16	14.0	1992.0	104.4
	4	16.38	14.9	2025.0	104.6
1962	1	16.66	14.6	2041.0	104.8
	2	15.99	14.9	2061.0	105.2
	3	18.54	14.9	2069.0	105.7
	4	16.48	15.7	2081.0	105.9

Table 8. (Continued)

		A Price of live hogs, Omaha ($/100 wt.)	B Pork farm wholesale margin (cents)	C Disposable income per capita (dollars)	D Consumer price index 57-59 = 100
1963	1	15.01	15.4	2105.0	106.1
	2	15.27	14.2	2119.0	106.3
	3	17.31	14.9	2144.0	107.1
	4	14.69	16.1	2173.0	107.4
1964	1	14.64	15.9	2217.0	107.6
	2	14.85	14.8	2272.0	107.9
	3	16.90	15.5	2302.0	108.3
	4	15.07	15.5	2327.0	108.7
1965	1	16.56	15.0	2353.0	108.9
	2	20.24	13.8	2392.0	109.7
	3	23.91	14.4	2466.0	110.1
	4	25.08	14.7	2513.0	110.7
1966	1	26.62	15.4	2549.0	111.5
	2	22.83	15.3	2574.0	112.7
	3	24.62	14.7	2616.0	113.7
	4	20.14	17.3	2656.0	114.6
1967	1	19.00	16.7	2689.0	114.8
	2	20.50	15.5	2722.0	115.6
	3	20.98	16.7	2761.0	116.8
	4	17.42	18.0	2800.0	117.8
1968	1	18.79	16.7	2868.0	119.0
	2	19.35	17.0	2928.0	120.4
	3	20.32	16.7	2956.0	121.9
	4	18.05	18.3	2999.0	122.8
1969	1	20.14	17.0	3023.0	124.8
	2	22.73	15.9	3070.0	126.9
	3	26.23	15.3	3148.0	128.7
	4	25.93	16.7	3188.0	130.5
1970	1	27.31	16.6	3272.0	132.5
	2	23.69	18.7	3353.0	134.6
	3	22.72	18.3	3395.0	136.1
	4	16.33	22.9	3410.0	138.2

Table 8. (Continued)

		E Civilian consumption (lb. per capita)			
		Pork	Beef	Broiler	Turkey
		(Carcass wts.)		(Ready-to-cook wts.)	
1955	1	17.2	19.6	2.7	0.4
	2	15.0	20.3	3.7	0.7
	3	15.0	21.5	4.0	1.1
	4	19.6	20.6	3.4	2.8
1956	1	18.6	21.3	3.6	0.5
	2	15.6	21.5	4.7	0.7
	3	15.1	21.3	4.8	1.1
	4	18.0	21.3	4.2	2.9
1957	1	15.8	21.5	4.1	0.5
	2	14.5	20.8	5.0	0.8
	3	13.9	21.6	5.2	1.3
	4	16.9	20.7	4.8	3.3
1958	1	15.0	19.5	4.6	0.5
	2	14.1	19.8	5.6	0.8
	3	14.2	21.0	6.4	1.3
	4	16.9	20.2	5.4	3.3
1959	1	16.7	19.1	5.2	0.6
	2	15.7	20.4	6.4	0.8
	3	16.0	21.3	6.2	1.4
	4	19.2	20.6	5.0	3.5
1960	1	17.5	20.9	5.1	0.6
	2	15.6	20.9	6.2	0.8
	3	15.1	22.4	6.6	1.3
	4	16.7	20.9	5.5	3.4
1961	1	15.8	20.9	5.4	0.6
	2	15.0	22.3	7.4	1.0
	3	14.2	22.6	7.3	1.7
	4	17.0	22.0	5.7	4.1
1962	1	16.2	22.0	5.6	0.7
	2	15.4	22.1	7.0	0.9
	3	14.5	22.9	6.8	1.5
	4	17.4	21.9	6.3	3.9

Table 8. (Continued)

		E Civilian consumption (lb. per capita)			
		Pork	Beef	Broiler	Turkey
		(Carcass wts.)		(Ready-to-cook wts.)	
1963	1	16.4	22.5	6.1	0.5
	2	15.8	23.5	7.1	0.9
	3	15.2	24.5	7.4	1.5
	4	18.0	24.0	6.4	3.9
1964	1	16.7	23.9	6.4	0.7
	2	15.5	25.5	7.4	0.9
	3	15.2	25.3	7.4	1.8
	4	18.0	25.2	6.4	4.0
1965	1	15.8	24.6	6.6	0.7
	2	14.5	24.0	7.7	0.9
	3	13.8	25.4	8.1	1.8
	4	14.6	25.5	7.1	4.1
1966	1	13.8	25.4	7.2	0.7
	2	13.9	25.6	8.3	1.0
	3	13.9	26.9	8.8	2.0
	4	16.5	26.3	8.0	4.1
1967	1	16.5	26.4	7.6	0.8
	2	15.0	26.8	8.7	1.1
	3	15.4	26.9	8.7	2.2
	4	17.2	26.4	7.8	4.5
1968	1	16.6	27.1	7.7	0.9
	2	15.8	26.8	8.4	1.1
	3	15.9	28.3	8.9	1.9
	4	17.9	27.5	8.1	4.0
1969	1	17.0	27.2	8.0	1.0
	2	16.0	26.7	9.1	1.2
	3	15.5	28.6	9.3	2.0
	4	16.5	28.3	8.8	4.1
1970	1	15.4	28.3	8.8	0.9
	2	15.6	27.9	9.9	1.0
	3	16.3	29.0	9.8	2.1
	4	19.1	28.5	8.8	4.1