A STATIC ANALYSIS OF THE ELASTICITY
OF DEMAND FOR BEEF

by

CHARLES FREDRICK MARSH

B.S., Kansas State College of Agriculture
and Applied Science, 1949

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agricultural Economics

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1955

TABLE OF CONTENTS

INTRODUCTION

A study of the demand for agricultural products is important because of the many questions which must be answered if agricultural production planning is to be carried out intelligently. Is it possible to forecast the effect of a change in quantity on price? Can the effect of a price change be predicted on the basis of the demand habits observed in past years? How does a gradual increase in the general income level influence demand? If the average real income continues to rise will this mean that more of the protein-rich animal foods and the vitamin-rich fruits and vegetables will be substituted for the lower cost cereals? These are just a few of the questions which are present in the field of application of demand analysis.

The subject is complicated in that "competent analysis of demand requires three things. First the economist must have a thorough knowledge of the economic factors that affect the commodity and obtain adequate data on which to base the analysis. Second, he must understand economic theory in general. Third, he must be able to use modern techniques of analysis."[1]

The development of statistical analysis of demand is a product of the present century. Although pioneer attempts were

---

[1]Richard J. Foote and Karl A. Fox, "Analytical Tools for Measuring Demand," Agriculture Handbook No. 64, USDA Agricultural Marketing Service, Washington, D. C., January 1954.

made earlier, most applied work in this field began after World War I. Statistical analysis of demand was slow in developing for two reasons: (1) it depends upon both economic and statistical theory; (2) it depends upon the quality and accuracy of published economic data.

Economic theory for analyzing demand was available at an early date, but statistical concepts applicable to demand analysis were not available until after the 1890's. Economic data relating to production, consumption, and income were also slow in developing. In this country reliable consumption and income data date back to the 1930's. Prior to World War I and through the 1920's agricultural price data were also very inadequate. At the present time, wholesale and retail price data are still lacking for many commodities.

After World War I, studies in this field increased rapidly. Today, demand analysis of some kind exists for practically all agricultural products. It is not surprising, however, that questions concerning methodology still remain unsettled and the number of generally accepted results is, therefore, limited.

Most demand studies have used annual data over a rather long period of time. It was necessary in these studies to adjust for population and price changes and include income and time as variables in the demand equations. One of the weaknesses of this method, however, is the fact that, though prices are deflated, this does not account for the income effect caused by the change in prices. These demand studies use the dynamic demand function, $x_1 = f(y_1, \ldots y_n, R, t)$, where x_1 and y_1 represent the consumption and price of the commodity being studied, . . . y_n represents the prices of other commodities, R represents income, and t, tastes which change over time.

This study is an attempt to derive the demand function for beef using a static model and monthly data over a short period of time. Pork was considered a priori to be the most important commodity competing with beef and was selected to be used with beef in the analysis.

The objectives of the study were: (1) to investigate the validity of the static model in attempting to measure demand, using monthly data; (2) to derive a simple demand function and elasticity of demand for beef alone; (3) to study the effects of changes in the price of pork on the demand for beef, or the cross-elasticity of demand; (4) to derive the demand function and elasticity for beef, when both beef and pork prices were used as variables in the demand equation.

It was recognized that the estimates of the elasticity of demand for beef made by this study would be only approximations. This was because of possible errors in the quantity and price series used and in the selection and use of the theoretical model and statistical technique. The accuracy of the estimates was also limited somewhat because only a small portion of the total demand surface was studied.

REVIEW OF THE PURE THEORY OF DEMAND

The theory of individual and collective demand is generally believed to be well established. However, modern writers of economic theory are still considering new properties of demand and reconsidering and revaluating the old accepted concepts. This section is devoted to a brief historical review of the pure theory of demand. The restatement and extension of some of the earlier concepts of demand into forms which have meaning in terms of operations is believed to be the first step in attempting to derive the statistical demand functions for a commodity.

Rather than rely upon the author's knowledge and understanding of the development of the theory of demand, it was thought best to combine the ideas and statements of some of the notable economists who have written creditable historical accounts in this field.

Static Concepts

More than a century ago, the law of demand was commonly stated as follows:

> At a given time and place, the price of a commodity rises in proportion to the increase of the demand and the decrease of the supply, and vice versa; or in other words, that the rise of price is in direct ratio to the demand, and inverse ratio to the supply.[1]

---

[1] Jean-Baptiste Say, Political Economy, p. 290.

If this statement is translated into mathematical symbols, it means that $P = \frac{D}{S}$, where P stands for price, D for quantity demanded, and S for the quantity supplied.

In 1838, Cournot cleared away some of the meaningless and sterile statements regarding demand and stated the law of demand in the following terms:

> Let us admit, . . . that the sales or the annual demand D is, for each article, a particular function F(p) of the price p of such article. To know the form of this function would be to know what we call the law of demand or sales.[1]

Mathematically Cournot's law is $D = F(p)$.

Alfred Marshall developed this concept and popularized it. According to Marshall:

> There is then one general law of demand: . . . The greater the amount to be sold, the smaller must be the price at which it is offered in order that it may find purchasers; or, in other words, the amount demanded increases with a fall in prices, and diminishes with a rise in price.[2]

Marshall again says: "The one universal rule to which the demand curve conforms is that it is inclined negatively throughout the whole of its length."[3]

Leon Walras, in 1873, was the first to write the demand for any commodity as a function of the prices of all commodities. In mathematical terms this means that the quantity of

---

[1]Augustin Cournot, Researches into the Mathematical Principles of the Theory of Wealth, trans. Bacon (New York, 1897), p. 47, as quoted in Henry Schultz, The Theory and Measurement of Demand, Chicago: University of Chicago Press, 1938, p. 6.

[2]Alfred Marshall, Principles of Economics, p. 99.

[3]Loc. cit.

any commodity purchased in a given interval of time must be expressed as a function not only of its price but also of all other prices, or $D = F(p_1, p_2, p_3, \ldots p_n)$, where D is the quantity of the commodity demanded, p_1, its price, and p_2, p_3, $\ldots p_n$ the prices of all commodities.

Cournot, Walras, Pareto, and most other mathematical economists make the price of the commodity (or the system of the prices considered) the independent variable in the demand equation. This practice is convenient in the treatment of general equilibrium, and it has the merit of suggesting that, to the individual purchaser, price fluctuations are independent of any action he can take. All he can do is to adjust himself to them.

The law of demand of the mathematical school includes the Cournot-Marshall law of demand, $D = F(p)$, as a special case. This is done by assuming constant values to all factors in the equation, $D = F(p_1, p_2, p_3, \ldots p_n)$, except the price and the quantity of the commodity in question. The level at which the other variables are assumed constant will determine the position of the demand curve obtained.

This designation of the ordinary demand curve as a special case of the general demand function is recognized as quite an improvement over the classical and neo-classical concepts. Schultz says:

> Though they talked about other variables, they never took the pains first to introduce them into their demand equation and then to assign them constant values. These economists never thought to

> raise the question whether it was always possible to keep other things constant, nor did they ever face the problem of the levels at which each of the "other things" might be kept constant.[1]

Dynamic Concepts

The way in which economists were led from the first law of demand, $P = \frac{D}{S}$, to the general formulation, $D = F(p_1, p_2, p_3, \ldots p_n)$, was done by hypothetically asking each prospective purchaser in the market, "How much will you buy of this commodity?" and of analyzing the probable replies. Most people must experience a given set of price relations in its proper institutional setting in order to make up their minds as to the quantities they will purchase. In short, the way to deduce the demand function for a commodity is to observe the behavior of consumers in masses in the market. Schultz explains:

> To obtain the probable form of the demand function, we must have numerous observations; and, in order to obtain the requisite number of observations, data covering a considerable period must, as a rule, be used. The pragmatic approach must, therefore, deal with variables (situations) which are functions of time.[2]

The law of demand then becomes, $D = F(p_1, p_2, p_3, \ldots p_n, t)$, where t stands for time, which includes all those factors that change slowly and smoothly with time. If t is given a particular date of interest, the Walrasian statical law of

---

[1]Schultz, _op. cit._, p. 9.

[2]_Ibid._, p. 10.

demand is obtained as a special case. If constant values are also assigned to all the p's except p_1, the Cournot-Marshall statical law of demand is obtained as another special case.

When income is also considered as affecting demand, the law of demand now becomes $D = F(p_1, p_2, p_3, \ldots p_n, R, t)$, where R stands for the size and distribution of income. This is the equation which Schultz gives for the dynamic law of demand. Income had been considered by other economists, but Pareto,[1] Slutsky,[2] and Hicks and Allen,[3] explicitly introduced income into the demand function. Schultz says: "for the study of the dynamics of demand, we need to know not only the direction of change of the system given by the statical equations, but also its velocity."[4] He explains that the best that can be done now is to "make a study of a series of statical equilibria, isolate their routine of change, and hope that this routine will continue to operate in the future."[5]

There is yet room for much progress in this field. According to Stigler:

> Economists have generally ignored the path by which equilibrium is reached and assumed that the path of approach had no effect on the equilibrium position, for two reasons. The first is that it is extremely difficult to analyze in detail the paths of movement, and in fact no very general theory of

---

[1] *Ibid.*, p. 36.
[2] *Ibid.*, p. 37.
[3] *Ibid.*, p. 46.
[4] *Ibid.*, p. 56.
[5] *Ibid.*, p. 58.

economic dynamics has yet been invented. The second reason is that it is possible to analyze statically a large and important area of problems and obtain correct results, that is, results conforming to observation.[1]

Individual and Market Demand

The individual demand schedule or function is generally assumed to express directly the observable fact that the individual consumer will, as a rule, buy increasing quantities of the same commodity at falling prices. For simplicity, the demand function is assumed to be a one-variable function. The individual may be thought to be buying one or several units of only one single commodity, or he may buy several commodities independent of each other. This gives the familiar demand curve, as a rule, falling strictly monotonically from left to right in a Cartesian plane. The ordinate shows quantities (the dependent variable) and the abscissa the price of the commodity in question.

Morgenstern, writing about individual demand, states that: "The points on the individual demand curve are a series of simultaneous alternative maximum bids for the quantities associated with each price."[2] The individual expresses a willingness to buy at a given moment of time either one or any of the other

---

[1]George J. Stigler, The Theory of Price, p. 43.

[2]Oskar Morgenstern, "Demand Theory Reconsidered," Quarterly Journal of Economics, February 1948, 62:168.

quantities at their respective prices. Morgenstern makes two observations:

> First, individual demand curves are short run except where goods are bought up to complete extinction of the wants they satisfy and if downward income changes will not effect the amount purchased. Second, when the individual demand curve of one variable is monotonically falling but remains single valued, it requires the assumption of an underlying decreasing marginal utility for additional units bought.[1]

Stigler observes that the "individual" consumer is usually a family.[2] He treats the family's composite decisions as those of a single person. Again he explains:

> The causes of variation among individuals and times can be classified under four headings: the price of the commodity; the prices of substitutes and complements; the income of individual; and tastes.[3]

So far concern has been with the behavior of a single individual. Economics, however, is more interested in the behavior of groups. An explanation of individual demand is a means to the study of collective or market demand. Stigler explains that "a market demand schedule is the sum of the schedules of the individuals in the market."[4] Morgenstern says: "Collective demand is generally understood as a summation of individual demand schedules of the individuals (for the same commodity)."[5]

---

[1] *Ibid.*, p. 174.
[2] Stigler, *op. cit.*, p. 43.
[3] *Loc. cit.*
[4] *Ibid.*, p. 57.
[5] Morgenstern, *op. cit.*, p. 175.

Stigler explains that the market demand curve will have a negative slope if the individual demand curves have negative slopes. The market demand curve will not show important discontinuities because of the variation among individuals in response to price changes. Hicks emphasizes that the market demand is divisible into two parts. One part corresponds to the sum of individual income effects and the other the sum of the individual substitution effects.[1]

Related Demand

During the development of the modern theory of utility, substantial contributions were made to the theory of demand. The introduction of the subjective theory of value into economic theory helped to throw some light on certain problems which could not be solved by a purely objective, behavioristic, operational approach. The early contributions of Jevons, Menger, Walras, Marshall, and Edgeworth did much to develop the utility theory. But Pareto later corrected and extended the work which had been done on the relation of utility to demand. Still later, Slutsky and Hicks and Allen explicitly introduced income into the demand function.[2] Those interested in the utility theory and its development will find Schultz's[3] and Hicks'[4] books excellent references.

---

[1]J. R. Hicks, Value and Capital, p. 34.
[2]Schultz, *op. cit.*, pp. 12-54.
[3]*Loc. cit.*
[4]Hicks, *op. cit.*, pp. 11-52.

The utility theory did provide a rational foundation for the law of demand, and with a generalization of the law, which brings out the interdependence of the various economic factors. It has enabled economists to classify commodities into useful and significant categories and to explain both the negatively and the positively sloping demand curves, thus providing a useful background for statistical work. It can be used as a means of determining whether certain forms of demand equations are consistent with given assumptions. Perhaps most important of all, the utility theory enables one to determine whether the behavior of consumers is consistent or rational, and whether commodities compete with or complete one another.[1]

It is sufficient to mention the well established theory that the higher the price of a commodity, the less of it a consumer will buy. The great variety in the responsiveness of quantity to price changes, or price elasticities, is equally well established. It is a tautology that commodities which have good substitutes have elastic demands. Stigler points out that if a commodity has an elastic demand, it probably has a good substitute, and if a commodity has an inelastic demand, it has no good substitutes.[2]

When the quantity demanded is a function of the single variable price, the elasticity of demand may be defined as the

---

[1]Schultz, op. cit., p. 54.
[2]Stigler, op. cit., p. 44.

ratio of the relative change in quantity demanded to the relative change in price, when the relative changes are infinitesimal.[1] In mathematical symbols, the formulation is $\eta xy = \frac{dx}{dy} \cdot \frac{y}{x}$. If the quantity demanded is regarded as a function of more than one variable, it is necessary to make use of the conception of partial elasticity of demand. The mathematical symbols again are $\eta xy \cdot t = \frac{\partial x}{\partial y} \cdot \frac{y}{x}$. In this notation the subscripts of η to the right of the dot represent the variables which are held constant, while those to the left of the dot are allowed to vary.

> When the coefficient of elasticity, , is equal to unit in absolute value, the demand is neither elastic nor inelastic, the same amount will be spent regardless of the price, and the demand curve is a "constant outlay curve." When is numerically greater than unity, the demand is elastic, and the lower the price, the greater the total expenditures on the commodity; when it is less than unity, the demand is inelastic, and the lower the price, the smaller the total expenditures.[2]

Stigler also discussed elasticity through time. The elasticity of demand for a commodity usually increases with the length of time a price change lasts. This is due to technological changes, imperfections in the market, and habit. He explained that most long run demand curves are elastic.[3]

Substitution or complementarity may be measured by the cross-elasticity of demand. Cross-elasticity of demand is the

---

[1] Schultz, op. cit., p. 190.
[2] Loc. cit.
[3] Stigler, op. cit., pp. 46-47.

change in the amount demanded of one good when the price of another good changes. If commodities are good substitutes, the cross-elasticity is large and positive. If commodities are good complements, the cross-elasticity of demand is large and negative. Economic substitution is defined by cross-elasticity.[1]

Schultz sums up the development of the general law of demand in the following way:

> With the development of his general law of demand Pareto has corrected, completed, and extended the work of Walras and others on the relation of utility to demand; with the explicit introduction of income into the demand function Slutsky, and later, Hicks and Allen have rendered a similar service to Pareto. Given the utility functions of the various commodities, we have learned how to express the demand for any one of them as a function of all the prices and of income and have seen that it is only when the commodities do not compete with each other that the quantity demanded will always decrease as price increases.[2]

Hicks sums up the law of demand by saying:

> The demand curve for a commodity must slope downwards, more being consumed when the price falls, in all cases when the commodity is not an inferior good. Even if it is an inferior good, so that the income effect is negative, the demand curve will still behave in an orthodox manner so long as the proportion of income spent upon the commodity is small, so that the income effect is small. Even if neither of these conditions is satisfied, so that the commodity is an inferior good which plays an important part in the budgets of its consumers, it still does not necessarily follow that a fall in price will diminish the amount demanded. For even a large negative income effect may be outweighed by a large substitution effect.[3]

---

[1] Ibid., p. 49.
[2] Schultz, op. cit., p. 50.
[3] Hicks, op. cit., p. 35.

> Thus, as we might expect, the simple law of demand--the downward slope of the demand curve--turns out to be almost infallible in its working. Exceptions to it are rare and unimportant.[1]

A REVIEW OF THE METHODS OF DERIVING DEMAND FROM STATISTICS

It will suffice for this study to give a brief review of studies of demand. Marshall as far back as 1885 said: "I believe that inductions with regard to the elasticity of demand, and deduction based on them, have a great part to play in economic science."[2] Cournot had made a similar statement nearly a half century before.[3] But it was not until 1914 that the first definite attempt was made at deriving demand from statistics. Schultz says:

> In that year Professor Henry L. Moore published his Economic Cycles: Their Law and Cause, in which he obtained equations expressing the relations between the quantities demanded and the prices of corn, hay, oats, and potatoes; determined the precision of these equations as formulas for estimating prices; and measured the elasticity of demand for each crop.[4]

Pigou in 1910 and Tschayanow in 1912 anticipated studies similar to Moore's. In the same year that Moore published his book, R. A. Lehfeldt published an estimate of the elasticity

---

[1] *Loc. cit.*

[2] Alfred Marshall, "On the Graphic Method of Statistics," Jubilee Volume of the Royal Statistical Society (London, 1885), p. 260, as quoted in Schultz, *op. cit.*, p. 63.

[3] Augustin Cournot, Researches Into the Mathematical Principles of the Theory of Wealth (1838) trans. N. T. Bacon (2nd ed., New York, 1927), p. 24, as quoted in Schultz, *op. cit.*, p. 63.

[4] Schultz, *op. cit.*, p. 63.

of demand for wheat.[1] In 1891, a book was written by Arthur B. and Henry Farquhar in which procedures very similar to Moore's were presented.[2] Benini in 1907 wrote a paper in which he derived the demand for coffee in Italy using multiple correlation.[3] Lenoir published a book, Études sur la formation et mouvement des prix, in 1913 in which similar ideas were expressed.[4] But none of these men received attention as did Moore. Apparently they did not cover so wide a field or succeed so well in obtaining new knowledge.

According to Schultz, Moore's methods have been used in most of the work since done in the statistical study of demand. He points out that such well-known statisticians as Ezekiel, Bean, Warren, Pearson, and Holbrook Working and E. J. Working have used Moore's methods as the foundation for their work. Much of the price analysis which has been carried on by statisticians of the federal and state governments have been influenced by Moore's methods.[5]

In more recent years new attacks have been made on the problem. These new attempts at deriving the demand curve and elasticity of demand use income data or family-budget data instead of time series of prices and quantities. This could be

---

[1] Loc. cit.
[2] Ibid., p. 64.
[3] Loc. cit.
[4] Loc. cit.
[5] Loc. cit.

said to be a revival and development of Pigou's methods.[1] Among those connected with these methods are Frisch (1926 and 1932), Fisher (1927), Roy (1930), and Marschak (1931).[2]

Moore restated the statical law of demand in a form permitting concrete, inductive treatment. He devised such methods as link relatives and trend ratios for handling the time variable and was among the first to apply multiple correlation to the study of demand. He succeeded in deducing for the first time the statistical demand curves for several important commodities, and in measuring their elasticities of demand. His statistical procedures consisted in the treatment of the problem statistically by the method of multiple correlation, the method of relative changes, the method of trend ratios, and combinations of these.

In the thirties came Allen-Bowley's and Schultz's books on consumer demand. These were the first comprehensive works in the field. The work of Allen and Bowley was based on family budget data and consumer demand was studied as a function of income.[3] Schultz had for his main purpose the study of demand as a function of prices. Schultz used time series data known

---

[1]A. C. Pigou, "A Method of Determining the Numerical Value of Elasticities of Demand," Economic Journal, 20 (1910), 636-40, as quoted in Schultz, op. cit., p. 107.

[2]Schultz, op. cit., p. 65.

[3]R. G. D. Allen and A. L. Bowley (1935), Family Expenditure, Staples, London, 145 pp., as cited by Herman Wold, Demand Analysis, p. 10 (Preface).

as market statistics and derived concrete statistical demand curves for sixteen different commodities.[1]

The recent work of Wold is based on a study of consumer demand in Sweden, carried out in 1938-40. Wold's main line of approach was to combine the analysis of family budget data and market statistics so as to obtain a unified picture of the demand structure in Sweden in 1920-38.[2]

Although statistical methods have changed a great deal over the years, generally speaking the least squares regression as traditionally used is still held by some to be a sound method, and especially legitimate for the purpose of demand analysis. Any statistical method cannot be applied blindly. If the regression coefficients obtained are to be accepted as legitimate for deriving demand elasticities, the economic sector under analysis must satisfy certain qualifying conditions.

Wold examines the least squares regression method throughout and his conclusion is that:

> The least squares method is highly flexible as regards the underlying assumptions and very simple as regards the numerical computations. The regression analysis as traditionally applied is essentially sound. In demand analysis, at least, it can still be safely recommended.[3]

Most of the recent work in attempting to measure demand has been done using the least squares single-equation method with different models or variations tried. Kuznets in a

---

[1]Schultz, op. cit., p. 133.
[2]Wold, op. cit.
[3]Ibid., p. 59.

discussion and comparison of statistical measurements says: "It appears to be possible to obtain 'sensible' results with any formulation that has been employed.---The alternative estimates appear to be equally 'acceptable.'"[1] He explains, however, that "there is undoubtedly a bias toward 'acceptable' estimates in published or semipublished studies; the really unsuccessful computations seldom reach the final stage."[2]

Since Haavelmo's first article on simultaneous equations approach, more interest has been directed to this method of measuring economic relationships.[3] However, Fox in discussing the measurement of demand for farm products comments:

> During the past few years my work in the United States Department of Agriculture has involved a considerable amount of statistical demand analysis. The object of this work has almost invariably been to obtain numerical results which "made sense" in terms of the commodities and classes of economic agents involved --that is, results of structural significance. In all but a few cases I have used single-equation methods for estimating the desired coefficients. I accept the proposition that many economic phenomena must be explained in terms of two or more simultaneous relationships. However, single-equation methods appear to be both practically and theoretically appropriate for estimating many structural relationships in the field of food and agriculture.[4]

---

[1] G. M. Kuznets, "Measurement of Market Demand with Particular Reference to Consumer Demand for Food," Journal of Farm Economics, December 1953, 35:878-897.

[2] Loc. cit.

[3] Trygve Haavelmo, "The Statistical Implications of a System of Simultaneous Equations," Econometrica, 11 (January, 1943), 1-12.

[4] Karl A. Fox, "Structural Analysis and the Measurement of Demand for Farm Products," Review of Economics and Statistics, 36:57-66, February 1954.

Other recent contributions to the development of techniques for measuring demand were made by Girshick,[1] Wahby,[2] Tintner,[3] Working,[4] and French.[5] There are many more who have made valuable contributions to the literature but which space does not permit this paper to include.

Most studies of the demand for beef have been made in conjunction with the study of demand for a group of food commodities. Schultz made a study of the interrelations of the demand for beef, pork, and mutton in the United States for the period, 1922-33. He used annual data which included the per capita consumption of beef, pork, and mutton respectively (in pounds), the deflated retail price of beef, pork, and mutton (in cents per pound), and the deflated per capita income (in dollars). By the use of multiple regression analysis Schultz derived the demand function for beef when prices of beef and pork and the income factor were the independent variables and per capita consumption of beef was the dependent variable in the regression equation. The following function was derived:

---

[1]M. A. Girshick and Trygve Haavelmo, "Statistical Analysis of the Demand for Food: Examples of Simultaneous Estimation of Structural Equations," Econometrica, 15:79-110, April 1947.

[2]Omar Wahby, "Econometric Analysis of Demands for Pork, Beef, and Poultry (Abstract)," Econometrica, 20:97-98, January 1952.

[3]Gerhard Tintner, "Multiple Regression for Systems of Equations," Econometrica, 14:5-36, January 1946.

[4]Elmer J. Working, "Studies in the Measurement of Demand with Special Reference to the Demand for Meat," Ph.D. Thesis, Harvard University, March 1952.

[5]Burton L. French, "The Statistical Determination of the Demand for Meat (Abstract)," Econometrica, 20:96, January 1952.

$Q_b = 66.3955 - 1.8999\ P_b + 0.1937\ P_p + 0.0680\ R$. This same function expressed in terms of constant elasticities was:
$Q_b = 1.0864 - 0.8754\ P_b' + 0.1212\ P_p + 0.6392\ R$.

Schultz concluded that the demand for beef is influenced more by its own price than by any other factor or by all the other factors taken together. He also concluded that beef competes with pork.[1]

Foote and Fox made a study of the demand for a great many food and livestock products in the United States for the period, 1922-41. The derived elasticity for beef (in per cent) at the retail and farm level when consumption of beef was the dependent variable was: - 0.79 and - 0.45 respectively. The elasticity at the farm level was derived by dividing the elasticity at the retail level (- 0.79) by the flexibility of farm price with respect to retail price (1.74).[2] Fox observes that the "elasticities of demand for most livestock products using retail prices and domestic consumption as variables, range between - 0.5 and - 1.0. If demand elasticities at the farm price level are derived from these, they center around - 0.5."[3] Fox also points out that demand elasticities at the farm level are somewhat more inelastic than at the retail level.

---

[1]Schultz, op. cit., pp. 638-640, pp. 646-647.

[2]Richard J. Foote and Karl A. Fox, Analytical Tools for Measuring Demand, U. S. Department of Agriculture, Washington: Government Printing Office, January 1954.

[3]Karl A. Fox, The Analysis of Demand for Farm Products, U. S. Department of Agriculture, Washington: Government Printing Office, Technical Bulletin No. 1081, September 1953, p. 4.

EXPLANATION OF METHODS AND PROCEDURE

The Economic Model

The parts of an economic model should be simple enough to manage and yet include all the important elements. Also assumptions upon which the model is based must allow realistic answers and must be clearly stated. A model should be looked upon as, "a blueprint of the existing economic structure, drawn in such a way that one can more readily establish the structural relationships among the economic variables for that portion of the economy under study."[1]

Models can be designed to aid in identifying the economic relationships among the different variables. They can also be designed so that statistical methods can be applied to available data and with given assumptions, parameters or coefficients can be determined.

A static theoretical model was first set up for this study. The dynamic demand function, $Q_b = f(P_b, P_p, \ldots P_n, R, t)$, was used as a starting point. Q_b and P_b represent the quantity of beef and the price of beef respectively, P_p represents the price of pork, $\ldots P_n$, the prices of all other commodities, R represents income, and t tastes which change slowly over time.[2]

---

[1]Anthony S. Rojko, "An Application of the Use of Economic Models to the Dairy Industry," Journal of Farm Economics, December 1953, 35:334.

[2]These symbols are used throughout the rest of the study.

It was next assumed for the purposes of this study that with the exception of the price of pork, the prices of all other commodities were constant. Thus the function, $Q_b = f(P_b, P_p, R, t)$, was obtained.

By the careful selection of a short period, 1952-53, during which the variable, income, remained relatively stable and during which it could be assumed tastes did not change, the static function, $Q_b = f(P_b, P_p)$, was obtained. This static model with some variations was used for the study.

A consumer when entering a store is confronted with a fixed beef price, bargaining being practically absent. When buying the quantity he desires, his transaction is very similar to the reaction in a stimulus-response experiment of the type known from experimental psychology. It is assumed that the buying response is not hindered by rationing and that the supplies of beef are sufficient to meet his demand.

Thus a unilateral dependence was recognized for beef. The relationship is unilateral in the sense that the consumption of beef is causally dependent upon the price of beef. In the customary terminology of experiments, the price of beef is the controlled variable, and consumption of beef is the effect variable.

It was first assumed that the quantity of beef consumed is a function of the price of beef, $Q_b = f(P_b)$. Fig. 1 shows the theoretical demand curve for beef with quantity consumed the dependent and the price of beef the independent variable.

If the price of beef is OM, then OB quantity of beef will be consumed. If the price of beef increases to OC, then the quantity consumed will be OA. A static condition was assumed in which the price of beef was the only factor affecting the consumption of beef, the price of pork being held constant. The demand schedule for beef, as shown in Fig. 1, depicts this static condition. It represents a series of simultaneous alternative bids for the quantities associated with each price. This gives the usual downward sloping demand curve wherein more beef will be consumed as the price of beef falls or conversely.

The theoretical relationship existing between beef and pork was next considered. Two commodities are said to be perfect substitutes if they can be substituted one for the other in a constant ratio. Beef and pork can be defined as substitutes if a rise in the price of one leads the consumer to buy more of the other. The strength of the relationship of substitution may be measured by the cross-elasticity of demand.

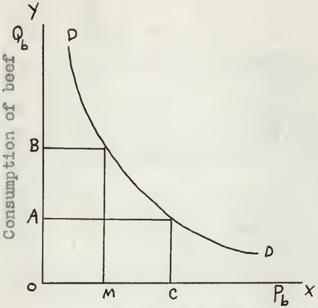
Fig. 2 indicates the theoretical relationship assumed to exist between the price of pork and the consumption of beef. The demand curve DD was derived from indifference curves for beef and pork. OA represents a constant price for beef. The price of pork is allowed to vary along line OX. With a given amount of income and the prices of beef and pork at OA and OB respectively, OE amount of beef will be consumed. As the price of pork increases from OB to OC, more beef will be purchased

EXPLANATION OF PLATE I

Fig. 1. The theoretical demand curve for beef.

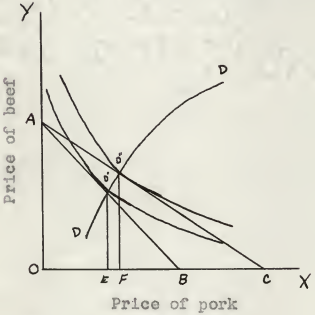
Fig. 2. The theoretical relationship assumed to exist between the price of pork and the consumption of beef.

PLATE I



Price of beef

Fig. 1



Price of pork

Fig. 2

out of the given income and the consumption of beef will increase from OE to OF on a higher indifference curve.

Two points, D' and D", have now been determined on the theoretical demand curve. If the price line were allowed to take all possible positions, all of the points of the demand curve, DD, would be secured.

It should be noted that, although the consumption of beef increases as the price of pork increases, each successive increment of increase in the price of pork results in smaller increments of increase in the consumption of beef. Theoretically a point could be reached where further increases in the price of pork would not result in any increased consumption of beef. This relationship gives a curve sloping positively toward the right. The mathematical equation again was a static one, $Q_b = f(P_p)$.

It was next assumed that the quantity of beef consumed is a function of the price of beef and also the price of pork. Fig. 3 pictures this relationship. A static mathematical model was set up, $Q_b = f(P_b, P_p)$. In Fig. 3 the same relationships are assumed to exist, except that both the price of beef and the price of pork are taken into consideration as affecting the quantity of beef consumed. Point B represents the theoretical quantity of beef consumed when the prices of beef and pork are relatively low. Point C represents the quantity of beef consumed when beef prices are high and pork prices relatively low. Point D represents the quantity of beef consumed

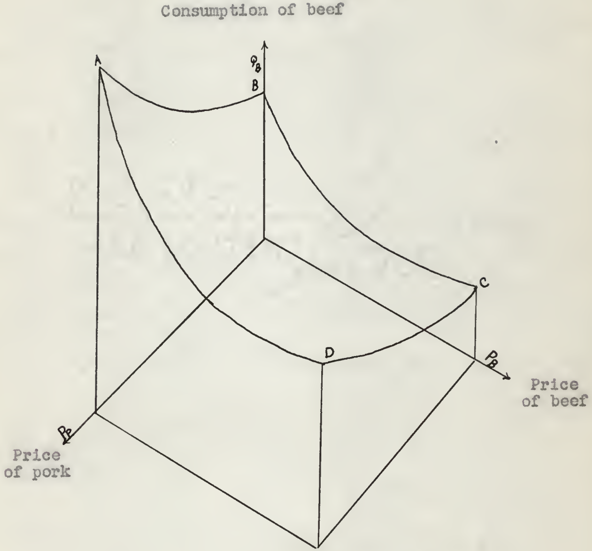


Fig. 3. The theoretical relationship and demand surface assumed to exist when both the price of beef and the price of pork are considered as affecting the quantity of beef consumed.

when beef and pork prices are both relatively high. Point A represents the quantity of beef consumed when beef prices are relatively low and pork prices high.

Theoretically if enough observations are taken and estimates made, the curves BC, DC, AD, and AB could be derived and the surface BCDA generated. It was believed that if static models could be used in which it could be assumed that other factors remain relatively stable, and if data could be obtained which would fit these conditions, a more realistic approach could be made to the measurement of the demand for beef.

Selection of Data and Statistical Techniques

Monthly market statistics for beef were used for the years 1952 and 1953. The reason for selecting a relatively short period of time for the analysis was to approximate as nearly as possible the static assumptions of the theoretical model employed.

The years 1952 and 1953 were rather stable years as far as economic activity is concerned. Prior to World War II the country had experienced one of the worst depressions in its history and recovery was not yet complete at the time war broke out in 1941. Then came the war years with the many restrictions upon production and consumption.

Following the close of World War II and again with the Korean outbreak in 1950, the cyclical upswing in business initiated in mid-1949 proceeded steadily, broadly based upon a resurgence of investment activity and the strong consumer demand for durable goods.[1] During the year 1950 prices, employment, and wages climbed to new heights. In an attempt to arrest the upward spiral fiscal measures were taken in the last half of 1950 in the form of credit controls, reinforced direct controls of prices and wages and higher Federal tax rates.

This upsurge in business activity continued through most of 1951. According to the Survey of Current Business, there was resumption of a more balanced growth in production in 1952, following the sharply divergent movements of the preceding year. This was due to the cessation of the sharp rate of increase in defense spending and the stabilization of private expenditures for defense-supporting plant and equipment.

With the exception of farm prices, most prices were relatively stable during 1952. Disposable personal income did increase about 4 per cent but this increase was largely matched by relative increases in consumer prices and population. Employment showed a slight increase during the closing months of 1952.[2]

Prices were again generally stable throughout 1953 in both the consumer and wholesale markets.

> The 1953 average of the Bureau of Labor Statistics index of consumer prices was 0.8 per cent above that of

---

[1]U. S. Department of Commerce, Survey of Current Business, Washington, U. S. Government Printing Office, January 1954, p. 1.

[2]*Ibid.*, pp. 1-33.

> the previous year. The movement was largely accounted for by the continued rise of consumer service prices and rents, while consumer-goods prices leveled out.[1]

Disposable personal income increased about the same as in 1952, but increased consumer outlays for durable goods took up most of the increase in disposable income. Employment during 1953 showed some gains, however, there were sizable reductions during the third and fourth quarters.[2] Thus it could be said that the years 1952 and 1953 were years of high level but relatively stable economic activity. Prices were relatively stable and disposable income did not change markedly as compared to some other years.

Kuznets in a recent critical review of demand studies says:

> Can we be reasonably sure that the relations among the economic variables which we are attempting to measure are unaffected by concomitant changes in the social variables? The answer to this question is, probably, no, unless we restrict our analysis to a reasonably short period of time.[3]

E. L. Baum in a discussion of Kuznets' review says:

> The dynamic problem of social change which limits the temporal validity of static models might be approached on a basis similar to some of the older techniques of time series analysis; that is conduct a series of successive estimates based on a fixed but short time period (if possible, much less duration than the full available data) and subsequently analyze the movement of the estimates of the parameters through

---

[1]Survey of Current Business, February 1954, p. 4.
[2]Ibid., pp. 1-24.
[3]G. M. Kuznets, "Critical Review of Demand Studies," Journal of Farm Economics, 35:893, December 1953.

> time. . . . The use of shorter time periods for data (e.g., monthly instead of annual) may increase the possibilities of accomplishing this.[1]

The monthly per capita consumption figures shown in Table 1 were derived by dividing the total disappearance figure for beef each month by the total population figure for the first of January of each year. Children born during the year were not considered consumers of beef.

The total disappearance figures (Table 1) were derived by adding to (or subtracting from) the total production of beef for each month changes in cold storage holdings and changes in exports and imports.[2]

Prices for beef and pork, Table 2, used were average monthly prices received by farmers in the United States.[3] These price data were selected because adequate wholesale or retail price data were not available. The use of market prices has merit in that beef is produced by thousands of independent producers who cannot individually change the market price--thus approximating the theoretical condition of perfect competition.

The method used in estimating the demand function for beef was least squares regression analysis. This is an old

---

[1]E. L. Baum, "Discussion, Critical Review of Demand Studies (by Kuznets)," Journal of Farm Economics, 35:896, December 1953.

[2]U.S.D.A. Agricultural Marketing Service, Market News, Chicago.

[3]U. S. Department of Agriculture, Livestock and Meat Situation, Washington: Government Printing Office, March 5, p. 27.

Table 1. Monthly total disappearance of beef in pounds and per capita consumption of beef for 1952 and 1953.

Month	Beef production for slaughter	Cold storage changes	Export import change	Total disappearance	Monthly per capita beef consumption
	(million lbs.)	(million lbs.)	(lbs.)	(lbs.)	(lbs.)[a]
1952					
January	810	9.8	2,511,859	802,711,859	5.154
February	721	16.9	2,923,655	717,023,655	4.604
March	685	3.9	1,108,121	682,208,121	4.380
April	703	-14.1	487,252	717,537,252	4.607
May	742	-16.5	1,230,226	759,730,226	4.878
June	698	-27.3	132,913	725,432,913	4.658
July	786	-24.0	- 426,631	809,573,369	5.198
August	793	- 5.3	16,298,979	814,598,979	5.230
September	841	10.4	23,239,177	853,839,177	5.482
October	933	31.0	10,614,606	912,614,606	5.859
November	768	29.2	6,984,381	745,784,381	4.788
December	857	48.5	3,789,254	812,289,254	5.215
1953					
January	928	- 9.5	2,340,109	939,840,109	5.932
February	850	-12.6	1,103,066	863,703,066	5.451
March	933	-21.3	518,663	954,818,663	6.026
April	991	-13.9	- 140,352	1,004,759,648	6.341
May	963	-24.2	1,228,691	988,428,691	6.238
June	1,001	-16.8	- 133,754	1,017,666,246	6.423
July	1,036	-26.5	3,846,774	1,066,346,774	6.730
August	1,008	- 8.4	2,438,265	1,018,838,265	6.430
September	1,037	0.3	1,467,014	1,088,167,014	6.868
October	1,145	26.1	742,283	1,119,642,283	7.066
November	1,039	28.5	- 277,179	1,010,222,821	6.376
December	1,092	51.6	- 1,336,730	1,039,063,270	6.558

a Monthly per capita consumption was derived by dividing the total disappearance figure for each month by the total population as of January 1 for the years 1952 and 1953.
Source: U.S.D.A. Agricultural Marketing Service, Market News.

Table 2. The monthly per capita consumption of beef, price of beef, and price of pork, for years 1952 and 1953.

Month	Per capita consumption of beef (lbs.)	Beef price (Per 100 lbs.)	Pork price (Per 100 lbs.)
1952			
January	5.2	27.20	17.30
February	4.6	27.50	17.10
March	4.4	27.50	16.60
April	4.6	27.70	16.40
May	4.9	27.80	19.20
June	4.7	26.20	19.40
July	5.2	25.60	19.70
August	5.2	24.60	20.60
September	5.5	23.29	19.00
October	5.9	21.40	18.50
November	4.8	20.30	16.60
December	5.2	19.00	16.10
1953			
January	5.9	19.70	17.80
February	5.5	18.80	19.30
March	6.0	17.80	20.20
April	6.3	17.30	20.70
May	6.2	17.50	23.10
June	6.4	16.00	22.70
July	6.7	17.30	24.20
August	6.4	16.30	23.60
September	6.9	15.80	23.80
October	7.1	14.70	21.30
November	6.4	14.70	20.00
December	6.6	14.80	22.80

Source: U. S. Department of Agriculture, Livestock and Meat Situation, Washington: Government Printing Office, March 5, p. 27.

traditional method and is regarded by economists as being sound and especially legitimate for the purpose of demand analysis. It is highly flexible as regards the underlying assumptions and very simple as regards the numerical computations.[1]

The procedure was to use market statistics and by the use of linear regression analysis make estimates of the hypothetical demand function. In each case the demand function was derived for each single year 1952 and 1953, and for the combined years, 1952-53.

From the demand functions the elasticities and cross-elasticities of demand were derived. The convention which was adopted for comparing elasticities that vary from point to point on the demand surface was to consider as comparable those points on two different demand surfaces, whose coordinates contain the mean values of their independent variables.

EMPIRICAL AND STATISTICAL RESULTS

Scatter diagrams were first made from the data. Observation indicated the relationship to be linear. However, an analysis was made using curvilinear regression to see if a curve would fit the data better. Curvilinear analysis did not result in any better fit, so it was assumed for this study that the relationship was linear.

---

[1]Wold, op. cit., p. 59.

Fig. 4 shows the relationship which existed when per capita consumption of beef was the dependent, $Q_b = f(P_b)$, and price of beef the independent variable in the linear equation. The trend lines A'A', for 1952 and A"A" for 1953 indicate the relationship for the two single years and line AA shows the relationships for the two years combined. The demand functions derived were:

$$1952\text{-}\quad Q_b = 6.8739 - \underset{(0.1335)}{0.07479}P_b \quad (r = 0.546) \quad (\sigma_{y_s} = 0.4041)$$

$$1953\text{-}\quad Q_b = 9.8738 - \underset{(0.1664)}{0.2097}P_b \quad (r = 0.775) \quad (\sigma_{y_s} = 0.3649)$$

$$1952\text{-}53\text{-}\quad Q_b = 8.8120 - \underset{(0.0775)}{0.1502}P_b \quad (r = 0.891) \quad (\sigma_{y_s} = 0.2672)$$

The corresponding elasticities of demand derived were - 0.37, - 0.55 and - 0.55 for the years 1952, 1953 and 1952-53 respectively. The figures in parentheses beneath the regression terms represent the standard errors of these terms. These standard errors as well as the standard errors from regression represented by σ_{y_s} are in pounds.

The regression coefficients all being negative indicate that, other things being equal, an increase in the price of beef was associated with a decrease in its consumption. The coefficients of correlation, (r), are all significant and, with the exception of the coefficient for 1952, are relatively high. The standard errors from regression are relatively small which indicates that the fitted curves were in good agreement with the observations.

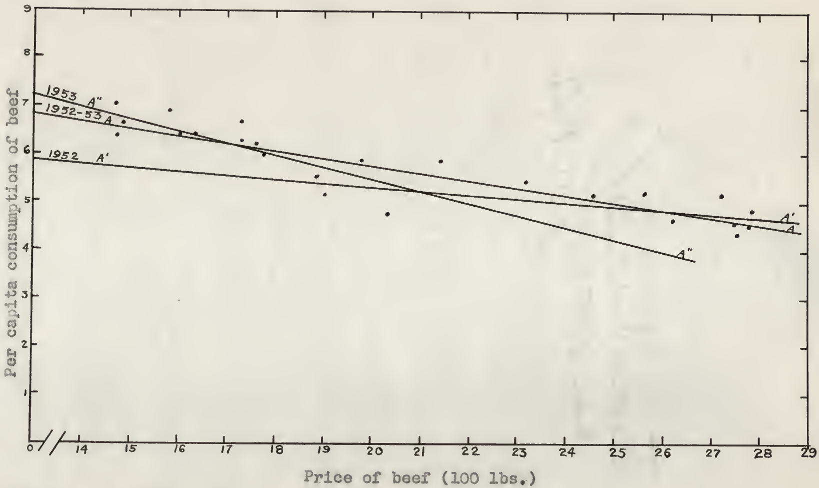


Fig. 4. Scatter diagram of the per capita consumption of beef and the corresponding price received by farmers. A'A', A"A", and AA are the lines of regression of per capita consumption on price for 1952, 1953, and 1952-53.

The scatter diagram shows a definite cluster of observations for each year. Results obtained were better where the combined years' data were used. The linear demand function fit the combined data much better resulting in a higher coefficient of correlation. For the combined years 1952-53, approximately 79 per cent of the variation was accounted for by the two variables.

The slope of the demand curves A'A' and A"A" and the corresponding elasticities, - 0.37 and - 0.55, indicate that the demand for beef was a little more elastic in 1953 than 1952. This might be explained by the fact that though beef prices dropped in the closing months of 1952, the full effect of this drop on the consumption of beef was not felt immediately. This lagged effect along with the continued drop in the price of beef during 1953 may explain why the demand curve A"A" is more elastic.

Fig. 5 shows the interrelationship of the demand for beef when price of pork is the independent variable, $Q_b = f(P_p)$, in the linear equation. The following demand functions were derived:

$$1952\text{-}\ Q_b = 3.0053 + \underset{(0.2573)}{0.1115P_p} \quad (r = 0.400) \quad (\hat{y}_s = 0.3764)$$

$$1953\text{-}\ Q_b = 3.4102 + \underset{(0.1687)}{0.1367P_p} \quad (r = 0.633) \quad (\hat{y}_s = 0.4699)$$

$$1952\text{-}53\text{-}\ Q_b = 0.5945 + \underset{(0.1889)}{0.2570P_p} \quad (r = 0.808) \quad (\hat{y}_s = 0.3292)$$

The cross-elasticities derived were 0.40, 0.46, and 0.89 for the years 1952, 1953 and 1952-53 respectively.

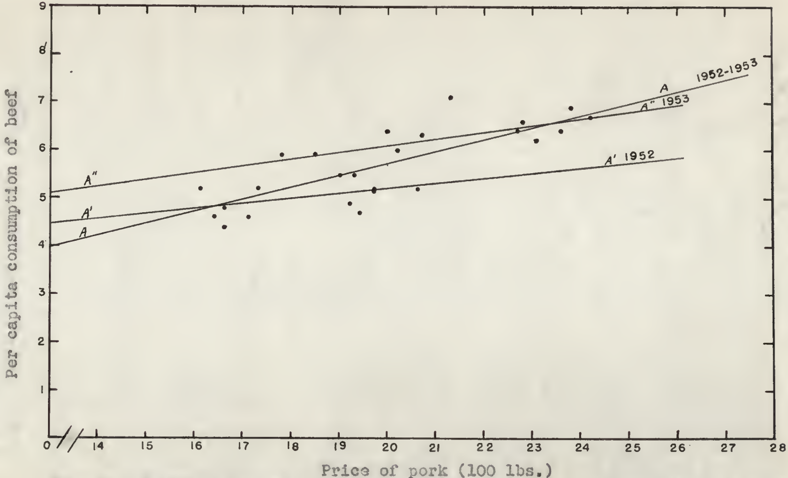


Fig. 5. Scatter diagram of the per capita consumption of beef and the price received by farmers for pork. A'A', A"A", and AA are the lines of regression of per capita consumption of beef on pork prices for 1952, 1953, and 1952-53.

The scatter diagram again shows a definite cluster for each year. The combined years', 1952-53, data gave a better fit and a much higher correlation coefficient.

The regression terms were all positive indicating that a rise in pork prices is associated with an increase in the consumption of beef. The cross-elasticity of 0.89 for the combined years 1952-53 is higher due to the fact that the effects of changes in the price of beef on the consumption of beef are present here but not accounted for.

Fig. 6, 7, and 8 show the relationship when the per capita consumption of beef was the dependent and price of beef and price of pork the independent variables in the multiple regression equation. The curves A'A', A"A", and AA were derived by first plotting the residuals from the regression of consumption of beef on the price of beef against the price of pork. A line was then drawn through the mean of the pork prices having the same slope as the regression term for pork in the multiple regression equation.

The demand functions derived were as follows:

$$1952\text{-}\ Q_b = 4.6416 - \underset{(0.02688)}{0.08478P_b} + \underset{(0.05523)}{0.1375P_p}\ (R = 0.726)(\hat{y}_s = 0.279)$$

$$1953\text{-}\ Q_b = 7.5579 - \underset{(0.0428)}{0.1655P_b} + \underset{(0.0342)}{0.07293P_p}\ (R = 0.832)(\hat{y}_s = 0.230)$$

$$1952\text{-}53\text{-}\ Q_b = 5.4644 - \underset{(0.0153)}{0.1073P_b} + \underset{(0.02624)}{0.1239P_p}\ (R = 0.938)(\hat{y}_s = 0.269)$$

The multiple R's for the three equations were relatively high. For the combined years, 1952-53, approximately 88 per cent

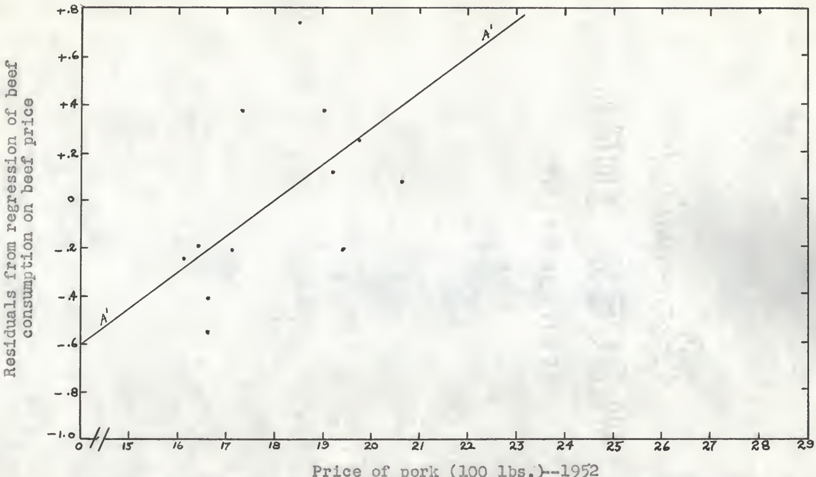


Fig. 6. Price of pork plotted against the residuals of the regression of beef consumption on beef price. A'A' is a line drawn through the mean of the pork price having the same slope as the regression term for pork in the multiple regression equation.

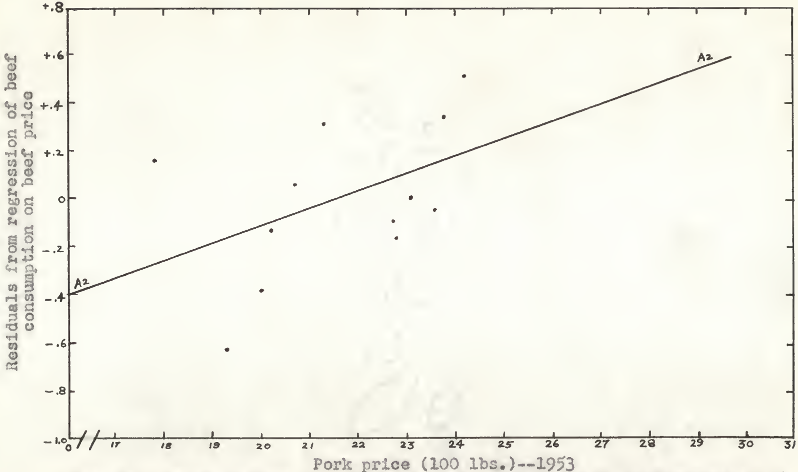


Fig. 7. Price of pork plotted against the residuals of the regression of beef consumption on beef price. A^2A^2 is a line drawn through the mean of the pork price having the same slope as the regression term for pork in the multiple regression equation.

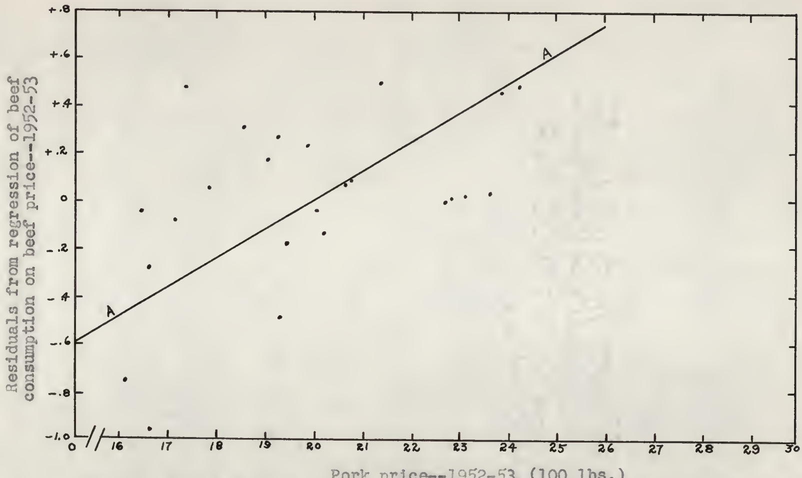


Fig. 8. Price of pork plotted against the residuals of the regression of beef consumption on beef price. A A is a line drawn through the mean of the pork price having the same slope as the regression term for pork in the multiple regression equation.

of the variation was accounted for by the three variables. The results obtained were again better for the combined years.

The regression terms and elasticities were negative indicating that a rise in the price of beef was associated with a decrease in its consumption. The cross-elasticities were positive indicating that a rise in the price of pork was associated with an increase in the consumption of beef.

The standard errors of the regression coefficients were quite small as compared to those for the simple linear regression equations. The standard errors from regression, σ_{ys}, were relatively small, being near one-fourth pound.

The following elasticities were derived:

1952- $P_b = -0.42$, $P_p = 0.50$

1953- $P_b = -0.43$, $P_p = 0.25$

1952-53- $P_b = -0.39$, $P_p = 0.43$

The following fudicial limits were placed on the multiple regression coefficients:

(1952)	$-0.08478P_b$,	$l_1 = -.1447$,	$l_2 = -.02489$
	$+0.1375P_p$,	$l_1 = .0144$,	$l_2 = .2606$
(1953)	$-0.1655P_b$,	$l_1 = -.2609$,	$l_2 = -.0701$
	$+0.07293P_p$,	$l_1 = -.00327$,	$l_2 = .1491$
(1952-53)	$-0.1073P_b$,	$l_1 = -.1390$,	$l_2 = -.0756$
	$+0.1239P_p$	$l_1 = .06948$,	$l_2 = .1783$

Fig. 9 shows the actual surface generated by the analysis. It is recognized that these straight line curves are only an approximation of the true demand curves. If enough observations had been taken and estimates made, theoretically, at least, the demand surface for beef would be composed of curves similar to those in Fig. 3. Only a small portion of the demand

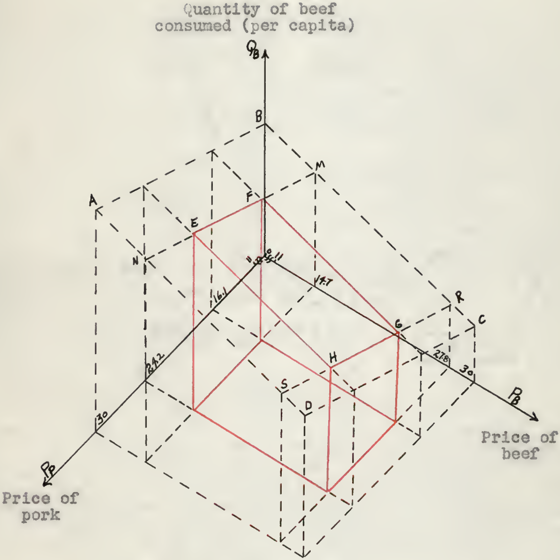


Fig. 9. Three dimensional diagram showing the actual relationship which existed between the per capita consumption of beef and the price of beef and pork and the actual demand surface EFGH generated by the multiple regression analysis.

surface for beef represented by the small figure, EFGH, was studied in this analysis. By extrapolation the large surface, ABCD, was derived.

SUMMARY AND CONCLUSIONS

In demand analysis as based on empirical data, there is no model that is known a priori to be true. Such models as are used, serve as tentative hypotheses, and the statistical analysis results in estimates of the hypothetical demand functions. If the estimates of the hypothetical demand functions are to prove useful as indicators of the true parameters, a judicious selection and application of the empirical data used is essential in order that the conditions set forth by the theoretical model employed may more nearly be satisfied.

This study of the demand for beef employed a static model. Monthly data of per capita consumption of beef and average prices received by farmers for beef and pork were used for the two year period 1952 and 1953. During this short period economic activity remained at a high level and prices, income, and employment remained relatively stable. Thus it was assumed for the study that income and tastes remained constant.

Pork was assumed to be the chief competing commodity, the prices of all other commodities being held constant. By the use of linear least squares regression and multiple regression analysis the demand functions and elasticities for beef and the cross-elasticities for pork were derived.

The results obtained from the simple linear regression equations showed a higher coefficient of correlation for the year 1953 as compared to 1952. This was true of both the elasticity of demand for beef alone and also the cross-elasticity for pork. Where the prices of both beef and pork were used as independent variables in a multiple regression equation, the results obtained were even better, showing a rather high correlation and small standard errors.

The most important aspect of the results obtained would appear to be the relative size of the regression coefficients and the corresponding elasticities. In each case the regression coefficient and elasticity was negative for beef price and positive for pork price. This indicates that an increase in the price of beef is associated with a decrease in its consumption and an increase in the price of pork is associated with an increase in the consumption of beef. It would also appear from the relative size of the regression terms and elasticities that the demand for beef is about as sensitive to changes in the price of pork as it is to changes in the price of beef. Based on the statistical analysis of this study, the conclusion would be that beef competes with pork.

The regression terms and elasticities were relatively small in most cases, indicating that the demand for beef with respect to price may be somewhat inelastic. The fact that the elasticity of demand at the farm level is usually more inelastic and also the fact that the longer a price change persists the more elastic will be the demand may explain why the demand for beef is probably somewhat more elastic than the results of this study indicate.

The constant elasticities of demand derived by Schultz in the multiple regression equation cited on page 21 were $- 0.3754P_b$ and $0.1212P_p$ for beef and pork respectively. The function $Q_b = 5.4644 - 0.1073P_b + 0.1239P_p$ with the corresponding elasticities, $P_b = - 0.39$ and $P_p = 0.43$, derived by this study is somewhat different than Schultz's function showed. A possible explanation is that twenty years or more ago the consumption of beef was limited because it was a highly perishable commodity and the facilities for preserving and storing beef were quite limited. The rather recent introduction of frozen food lockers and of "deep freeze" units in private homes as well as the improved methods for holding meat in cold storage may have had the tendency to increase the competition between beef and pork. During this particular period and more especially, for the year 1953, the relatively high prices of pork and the low prices of beef would certainly have a tendency to increase this effect.

As previously stated, Fox found that most of the demand elasticities for livestock products at the retail level range between - 0.5 and - 1.0.

In the light of the results of this study it would appear that the static model using monthly data can be used in demand analysis studies with at least some degree of confidence. The theoretical assumptions set forth by the model were generally satisfied by the statistical functions derived and the estimates of elasticity made.

The method followed here, theoretically at least, was an attempt to measure demand during a period when several important factors (but not all) that might affect the demand for beef were assumed to be constant. Strictly speaking, elasticity of demand usually represents, either a very short distance on a demand curve or a point if the curve is a straight line. Thus these estimates of elasticity cannot be used indiscriminately in predicting demand at a future time.

If several carefully designed surveys using monthly data could have been made and movements of the demand curve observed through time, more accurate estimates might have resulted. Selection of time periods, however, would have been a problem and dynamic factors would have had to be considered.

It is certainly of economic interest for policy makers of governmental bodies and marketing and production firms to know that the elasticity of demand for a particular food commodity or group of food commodities with respect to price is relatively low. Economists have suspected this of being true for over a century. However, it is important to have these theories or postulates confirmed by statistical analysis. As more and improved data are used and better statistical techniques for measuring demand are followed, the estimates of demand will, no doubt, approach much nearer the true values.

Aristotle once said, "The search for truth is in one way hard and in another easy, for it is evident that no one can master it fully nor miss it wholly. But each adds a little to our knowledge of Nature, and from all the facts assembled there arises a certain grandeur."[1]

---

[1]Metaphysis ia. 993a. 30--993b. 4. Quotation inscribed in Greek on the facade of the National Academy of Sciences Building in Washington, as quoted in Schultz, op. cit., p. 666.

ACKNOWLEDGMENT

Grateful acknowledgment is extended Dr. George Montgomery, Professor and Head of the Department of Economics and Sociology, and to the Department of Agricultural Economics of Kansas State College for the opportunity and assistance provided in making this study possible.

The Author gives special recognition to his Major Instructor, Lawrence W. Van Meir, Assistant Professor of Economics and Sociology, for his patient guidance and supervision of the study. Professor Van Meir gave unsparingly of his time and his suggestions and constructive criticisms were invaluable. Recognition and thanks are also made to Henry Tucker, Assistant Professor of Mathematics, for his helpful advice. The Author further wishes to extend thanks to Drs. Wilfred H. Pine, Professor of Agricultural Economics, Dale A. Knight, Assistant Professor of Agricultural Economics, and Kuan-I Chen, Assistant Instructor of Economics and Sociology, who read the manuscript and made helpful suggestions and criticisms. Dr. Chen also contributed many helpful ideas during the time the study was being made.

BIBLIOGRAPHY

Allen, R. G. D. and A. L. Bowley (1935). Family Expenditure. Staples, London, as quoted in Schultz, Henry. The Theory and Measurement of Demand. (1938).

Baum, E. L. "Discussion of Kuznets', 'Market Demand with Reference to Consumer Demand.'" Journal of Farm Economics, December 1953, 35:896.

Bennion, E. G. "The Cowles Commission's 'Simultaneous-Equation Approach': A Simplified Explanation." Review of Economics and Statistics, February 1952.

Bronfenbrenner, Jean. "Sources and Size of Least Squares Bias in a Two-Equation Model." Chapter 9, pp. 221-235 in Studies in Econometric Method, Cowles Commission Monograph 14, Wiley, 1953.

Burk, Marguerite C. "Changes in the Demand for Food from 1941-1950." Journal of Farm Economics, August 1951, 33:281-298.

Chernoff, H. and H. Rubin. "Asymptotic Properties of Limited Information Estimates under Generalized Conditions." Chapter 7, pp. 200-212 in Studies in Econometric Method, Cowles Commission Monograph No. 14, Wiley, 1953.

Cochrane, Willard W. "An Analysis of Farm Price Behavior." Pennsylvania State College, School of Agriculture, Progress Report No. 50, May 1951.

----------. and Harland C. Lampe. "The Nature of the Race Between Food Supplies and Demand in the United States." 1951-1975. Journal of Farm Economics, May 1953, 35:203-222.

Cournot, Augustin. Researches into the Mathematical Principles of the Theory of Wealth (1838) trans. N. T. Bacon (2nd ed.; New York, 1927), as quoted in Schultz, Henry. The Theory and Measurement of Demand. (1938).

Croxton, Frederick E. and Dudley J. Cowden. Applied General Statistics. New York: Prentice-Hall, 1939.

Duesenberry, James S. and Helen Kistin. "The Role of Demand in the Economic Structure." Chapter 12, pp. 451-482, in Wassily Leontief, Studies in the Structure of the American Economy, Oxford University Press: 1953.

Foote, Richard J. and Karl A. Fox. Analytical Tools for Measuring Demand. United States Department of Agriculture Handbook No. 64, Washington: Government Printing Office, January 1954.

Fox, Karl A. The Analysis of Demand for Farm Products. United States Department of Agriculture Technical Bulletin No. 1081, Washington: Government Printing Office, September 1953.

----------. "Structural Analysis and the Measurement of Demand for Farm Products." The Review of Economics and Statistics, February 1954, 36:57-66.

----------. "The Demand for Farm Products: An Appraisal of the Applicability of Single Equation Methods in Statistical Demand Analyses for Agricultural Commodities." Ph.D. Thesis, University of California, 1952.

French, Burton L. "The Statistical Determination of the Demand for Meat." (Abstract) Econometrica, January 1952, 20:96.

Geary, R. C. "Determination of Linear Relations Between Systematic Parts of Variables with Errors of Observation the Variances of Which are Unknown." Econometrica, January 1949, 17:30-58.

Girshick, M. A. and Trygve Haavelmo. "Statistical Analysis of the Demand for Food: Examples of Simultaneous Estimation of Structural Equations." Econometrica, April 1947, 15:79-110.

Haavelmo, Trygve. "Family Expenditures and the Marginal Propensity to Consume." Econometrica, October 1947, 15:335-341.

----------. "The Statistical Implications of a System of Simultaneous Equations." Econometrica, January 1943, 11:1-12.

Hicks, J. R. Value and Capital. London: Oxford University Press, 1950.

Hildreth, Clifford and Frank Jarrett. "A Statistical Study of Livestock Production and Marketing." Cowles Commission Discussion Paper (Economics No. 2055 and Statistics No. 375). November 13, 1952.

Houthakker, H. S. "Demand Analysis." Journal of the American Statistical Association, March 1954, pp. 88-96.

Judge, George G. "An Econometric Analysis of the Demand for Eggs." Ph.D. Thesis, Iowa State College, 1952.

Kuznets, G. M. "Measurement of Market Demand with Particular Reference to Consumer Demand for Food." Journal of Farm Economics, December 1953, 35:878-897.

Lebergott, Stanley. "Measurement for Economic Models." Journal of the American Statistical Association, June 1954, 49:209-226.

Marshall, Alfred. Principles of Economics. New York: Macmillan, 1948.

----------. "On the Graphic Method of Statistics." Jubilee Volume of the Royal Statistical Society (London, 1885), as quoted in Schultz, Henry. The Theory and Measurement of Demand. (1938).

Meyers, Albert L. Elements of Modern Economics. New York: Prentice-Hall, 1947.

Mighell, R. L. and R. H. Allen. "Demand Schedules--'Normal' and 'Instantaneous.'" Journal of Farm Economics, August 1939, 21:555-569.

Moore, Henry Ludwell. Synthetic Economics. New York: 1929, as quoted in Schultz, Henry. The Theory and Measurement of Demand. (1938).

Morgenstern, Oskar. "Demand Theory Reconsidered." Quarterly Journal of Economics, February 1948, 62:165-201.

Norris, Ruby Turner. "The Analysis of Demand." Quarterly Journal of Economics, November 1939, 54:131-142.

Pigou, A. C. "A Method of Determining the Numerical Value of Elasticities of Demand." Economic Journal, 20 (1910) 636-40, as quoted in Schultz, Henry. The Theory and Measurement of Demand. (1938).

Prest, A. R. "Some Experiments in Demand Analysis." The Review of Economics and Statistics, February 1949, 31:33-49.

Rojko, Anthony S. "An Application of the Use of Economic Models to the Dairy Industry." Journal of Farm Economics, December 1953, 35:834.

Samuelson, Paul A. Economics, An Introductory Analysis. New York: McGraw-Hill, 1951.

----------. Foundations of Economic Analysis. Cambridge: Harvard University Press, 1948.

Say, Jean-Baptiste. Treatise on Political Economy. Philadelphia: J. B. Lippincott, 1860.

Schultz, Henry. The Theory and Measurement of Demand. Chicago: University of Chicago Press, 1938.

Shepherd, Geoffrey. "Changes in the Demand for Meat and Dairy Products in the United States Since 1910." Iowa State Agricultural Experiment Station Research Bulletin 368, November 1949.

Shores, Lois N. "A System of Structural Equations Explaining the Demand for Food in the United States." M.A. Thesis, University of Chicago, October 1946.

Snedecor, George W. Statistical Methods. Iowa State College Press, 1946.

Stigler, George J. The Theory of Price. New York: Macmillan, 1954.

Tintner, Gerhard. "The Theory and Measurement of Demand." Journal of Farm Economics, August 1939, 21:606-613.

----------. "Multiple Regression for Systems of Equation." Econometrica, January 1946, 14:5-36.

----------. "Static Econometric Models and Their Empirical Verification, Illustrated by a Study of the American Meat Market." Metroeconomica, December 1950, 2:172-181.

United States Department of Agriculture, Agricultural Statistics. Washington: Government Printing Office, 1954.

United States Department of Agriculture, Agricultural Marketing Service. (Livestock Division) Market News. Chicago.

United States Department of Agriculture, Agricultural Marketing Service. (Livestock Division) Market News. Washington.

United States Department of Agriculture. Livestock and Meat Situation. Washington: Government Printing Office, March 5, 1954.

United States Department of Commerce, Survey of Current Business, Washington: Government Printing Office, January 1954.

Wahby, Omar. "Econometric Analysis of the Demands for Pork, Beef, and Poultry (Abstract)." Econometrica, January 1952, 20:97-98.

Wald, A. "Fitting of Straight Lines if Both Variables are Subject to Error." Annuals of Mathematical Statistics, September 1940, 11:284-300.

Wold, Herman. Demand Analysis. New York: John Wiley & Sons, 1953.

Working, Elmer J. "Studies in the Measurement of Demand with Special Reference to the Demand for Meat." Ph.D. Thesis, Harvard University, March 1952.

----------. "Appraising the Demand for American Agricultural Output During Rearmament." Journal of Farm Economics, May 1952, 34:206-224.

A STATIC ANALYSIS OF THE ELASTICITY
OF DEMAND FOR BEEF

by

CHARLES FREDRICK MARSH

B.S., Kansas State College of Agriculture
and Applied Science, 1949

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agricultural Economics

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1955

The development of statistical analysis of demand is a product of the present century. Although pioneer attempts were made earlier, most applied work in this field began after World War I.

Economic theory for analyzing demand was available at an early date, but statistical concepts applicable to demand analysis were not available until after the 1890's. Economic data relating to production, consumption, and income were also slow in developing. In this country reliable consumption and income data date back to the 1930's. Prior to World War I and through the 1920's agricultural price data were also very inadequate. At the present time, there is still a lack of published wholesale and retail price data for many commodities.

Empirical demand analysis supplies answers to the many questions regarding agricultural production planning. It attempts to derive real values for the theoretical demand functions. Thus it is of fundamental importance to theory as well as applications.

This study was an attempt to derive the demand function and elasticity of demand for beef with respect to the price of beef and the cross-elasticity of demand for beef with respect to the price of pork employing a static theoretical model. Monthly data of per capita consumption of beef and average prices received by farmers were used for the period 1952-53. During this period economic activity remained at a high level and prices, income, and employment remained relatively stable. By selecting this short period during which constant values could be assumed for income and tastes, it was possible to approximate rather closely the static assumptions of the economic model employed.

Pork was assumed to be the chief competing commodity, the prices of all other commodities were assumed constant for the study. By the methods of linear least squares regression and multiple regression analysis estimates of the demand functions for beef were derived.

Monthly per capita consumption figures used in the study were derived by dividing the total disappearance figure for beef each month by the total population figure for the first of January of each year. Total disappearance figures were derived by adding to (or subtracting from) the total production of beef for each month, changes in cold storage holdings and changes in exports and imports.

Average prices received by farmers for beef and pork were used because adequate wholesale or retail price data were not available. The use of market prices has merit in that beef is produced by thousands of independent producers who cannot individually change the market price--thus approximating the theoretical condition of perfect competition. It was recognized that the elasticities derived by the study would be somewhat more inelastic because market prices were used.

A unilateral dependence was recognized for beef. The relationship is unilateral in the sense that the consumption of beef is causally dependent upon the price of beef. In the customary terminology of experiments, the price of beef is the controlled variable, and consumption of beef is the effect variable.

The objectives of the study were: (1) to investigate the validity of the static model in attempting to measure demand, using monthly data; (2) to derive a simple demand function and elasticity of demand for beef, assuming the quantity of beef consumed to be a function of the price of beef, $Q_b = f(P_b)$; (3) to study the effects of changes in the price of pork on the quantity of beef consumed (cross-elasticity) assuming the quantity of beef consumed to be a function of the price of pork, $Q_b = f(P_p)$; (4) to derive the demand function, the elasticity of demand for beef, and the cross-elasticity with respect to pork when both beef and pork prices were used as independent variables in a multiple regression equation, $Q_b = f(P_b, P_p)$.

Scatter diagrams were first made from the data. Observation indicated the relationship to be linear. However, an analysis was made using curvilinear regression to see if a curve would fit the data better. Curvilinear regression did not result in any better fit, so it was assumed for this study that the relationship was linear.

The elasticities and cross-elasticities of demand were derived from the demand functions. The convention which was adopted for comparing elasticities that vary from point to point on the demand surface was to consider as comparable those points on two different demand surfaces, whose coordinates contain the mean values of their independent variables.

The mean values of the independent variables were substituted in the demand equations and the values of the dependent variables determined. When the quantity demanded was a function of the single variable price, the formula, $\eta xy = \frac{dx}{dy} \cdot \frac{y}{x}$, was used to derive the elasticities. When the quantity demanded was regarded as a function of more than one variable, the formula, $\eta xy \cdot t = \frac{\partial x}{\partial y} \cdot \frac{y}{x}$, was used to derive the elasticities.

The following demand functions were derived when the quantity of beef consumed was the dependent and price of beef the independent variable in the regression equation:

$$1952\text{-}\quad Q_b = 6.8739 - \underset{(0.1335)}{0.07479}P_b \quad (r = 0.546)\ (\hat{\sigma}_{y_s} = 0.4041)$$

$$1953\text{-}\quad Q_b = 9.3738 - \underset{(0.1664)}{0.2097}P_b \quad (r = 0.775)\ (\hat{\sigma}_{y_s} = 0.3649)$$

$$1952\text{-}53\text{-}\quad Q_b = 8.8120 - \underset{(0.0075)}{0.1502}P_b \quad (r = 0.391)\ (\hat{\sigma}_{y_s} = 0.2672)$$

The corresponding elasticities of demand derived were: - 0.37, - 0.55, and - 0.55. The figures in parentheses beneath the regression terms represent the standard errors of these terms. Simple correlation is represented by (r) and the standard deviation from regression is represented by ($\hat{\sigma}_{y_s}$).

The following demand functions were derived when the quantity of beef consumed was the dependent and price of pork the independent variable in the regression equation:

$$1952\text{-}\quad Q_b = 3.0053 - \underset{(0.2573)}{0.1115}P_p \quad (r = 0.400)\ (\hat{\sigma}_{y_s} = 0.3764)$$

$$1953\text{-}\quad Q_b = 3.4102 - \underset{(0.1687)}{0.1367}P_p \quad (r = 0.633)\ (\hat{\sigma}_{y_s} = 0.4699)$$

$$1952\text{-}53\text{-}\quad Q_b = 0.5945 - \underset{(0.1889)}{0.2570}P_p \quad (r = 0.808)\ (\hat{\sigma}_{y_s} = 0.3292)$$

The cross-elasticities derived were + 0.40, + 0.46, and + 0.89 for the years 1952, 1953, and 1952-53 respectively.

The demand functions derived when the quantity of beef consumed was the dependent and the prices of beef and pork were the independent variables in a multiple regression equation were:

$$
\begin{array}{rlll}
1952\text{-} & Q_b = 4.6416 - \underset{(0.02688)}{0.08478P_b} & + \underset{(0.05523)}{0.1375P_p} & (R = 0.726)(\hat{y}_s = 0.279) \\
1953\text{-} & Q_b = 7.5579 - \underset{(0.0428)}{0.1655P_b} & + \underset{(0.0342)}{0.07293P_p} & (R = 0.832)(\hat{y}_s = 0.230) \\
1952\text{-}53\text{-} & Q_b = 5.4644 - \underset{(0.0153)}{0.1073P_b} & + \underset{(0.02624)}{0.1239P_p} & (R = 0.938)(\hat{y}_s = 0.269)
\end{array}
$$

The corresponding elasticities and cross-elasticities were: 1952- - 0.42, 0.50; 1953- - 0.43, 0.25; 1952-53- - 0.39, 0.43. The following fudicial limits were placed on the multiple regression coefficients:

$$
\begin{array}{llll}
(1952) & - 0.08478P_b, & l_1 = -.1447, & l_2 = -.02489 \\
 & + 0.1375P_p, & l_1 = .0144, & l_2 = .2606 \\
(1953) & - 0.1655P_b, & l_1 = -.2609, & l_2 = -.0701 \\
 & + 0.07293P_p, & l_1 = -.00327, & l_2 = .1491 \\
(1952\text{-}53) & - 0.1073P_b, & l_1 = -.1390, & l_2 = -.0756 \\
 & + 0.1239P_p, & l_1 = .06948, & l_2 = .1783
\end{array}
$$

The results obtained from the simple linear regression equations showed a higher coefficient of correlation for the year 1953 as compared to 1952. This was true of both the elasticity of demand for beef alone and also the cross-elasticity with respect to pork. Where the prices of both beef and pork were used in a multiple regression equation, the results were even better showing a rather high correlation and small standard errors. Results were also better in each case where the combined years' data were used.

The coefficients of correlation are all significant at the 5 per cent level or below and relatively high with the exception of the linear regression equations for 1952 and the standard deviations from regression are relatively small which indicates that the fitted curves were in good agreement with the observations.

The most important aspect of the results obtained would appear to be the relative size of the regression coefficients and the corresponding elasticities. In each case the regression coefficient and elasticity was negative for beef price and positive for pork price. This indicates that an increase in the price of beef was associated with a decrease in its consumption and an increase in the price of pork was associated with an increase in the consumption of beef. It would also appear from the relative size of the regression terms and elasticities that the demand for beef was about as sensitive to changes in the price of pork as it was to changes in the price of beef. Based on the statistical results, the conclusion would be that beef competes with pork.

The regression terms and elasticities were relatively small in most cases, indicating that the demand for beef with respect to price was relatively inelastic. The fact that the elasticity of demand at the farm level is usually more inelastic and also the fact that the longer a price change persists the more elastic will be the demand may explain why the demand for beef was probably somewhat more elastic than the results of this study indicate.

In the light of the results of this study it would appear that the static model using monthly data can be used in demand analysis studies with at least some degree of confidence. The theoretical assumptions set forth by the model were generally satisfied by the statistical functions derived and the estimates of elasticity made. Elasticity of demand usually represents, either a very short distance on a demand curve or a point if the curve is a straight line. Thus the estimates of elasticity cannot be used indiscriminately in predicting demand at a future time.

If several carefully designed surveys using monthly data could have been made and movements of the demand curve observed through time, more accurate estimates might have resulted. Selection of time periods, however, would have been a problem and dynamic factors would have had to be considered.