THE CONTROLLED EXPERIMENT AS A DATA GENERATING MECHANISM FOR PRICE-RESPONSE RELATIONSHIPS

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I. INTRODUCTION

A. General Problem Area

Mankind is confronted with the perpetual problem of choice. A major barrier to intelligent choice is the lack of adequate knowledge relative to the consequences of alternative courses of action. Assuming that some degree of order exists in the world, abstractions from reality or "models" are constructed in an effort to increase the knowledge available for decision making.

Econometric techniques provide the decision maker with quantitative estimates of relationships that are essential for intelligent action. To do this, quantitative research in economics proceeds as follows: First, to formulate economic models; second, to collect appropriate data; and third, to confront models with data.[1] In such research, model formulation is vital since the model determines the framework for the remainder of the estimation process. Econometric models, based to a large extent upon economic theory combine with statistical data and the modern methods of statistical inference to provide many alternatives in the estimation process.

Any method of estimation derives its meaning and area of applicability from the concept of a well-defined sampling model. Koopmans has discussed this problem as follows:

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[1] J. Marschak, "Statistical Inference in Economics," contained in Statistical Inference in Dynamic Economic Models, New York: John Wiley and Sons, 1950, p. 1.

> "The solution to a problem of statistical inference in any field must be based on a consideration of the process that yields the observations from which the inference is to be drawn. It is sometimes useful to think of the scientist and nature (in our case, society) as cooperating in the process of obtaining observations. Three aspects of the generation of observations may then be delineated. First there are the processes of nature whereby the quantities to be measured are generated. Then there is the control over these processes exercised by the scientist through experimental techniques. Finally there is the matter of measurement itself, the measurements being made by or for the scientist but their exactness not entirely controlled by him. In some fields the experimental control exercised by the scientist is a more significant factor than in others. In economics it is of much less significance than in most. But in all cases the choice and the usefulness of a method of estimation or of testing hypotheses depend on the character (assumed or known) of the process generating the observations."[2]

The estimation of the parameters of behavior relationships have been based, for the most part, upon time series data. Time series data are generated by systems of relations that are in general, stochastic, dynamic, and simultaneous in nature.[3] The role of simultaneous equations is familiar to economic theorists. But it has often been forgotten by economic statisticians who tried to estimate a single stochastic relation as if no other relations had taken part in determining the observed values of the variables.[4]

Recent work in econometrics has stressed the importance of developing statistical methods to deal with the peculiarities of the data. In spite of advances, in many cases parameter estimation has proceeded with observations for which the supporting theory was not meant to hold. Thus, we

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[2] T. C. Koopmans and W. C. Hood, Studies in Econometric Methods, New York: John Wiley and Sons, 1953, pp. 113-114.

[3] Marschak, op. cit., p. 3.

[4] Ibid.

are constantly confronted with the questions: (1) have we observed what we meant to observe, and (2) do the measured variables actually have the properties of the theoretical variables?[5]

Such considerations point up the need for alternative ways of generating data for estimating our economic models other than the steady stream of poorly planned experiments turned out by our social laboratory.

One alternative is to permit the scientist to design economic experiments which would generate data potentially conformable with the underlying theoretical counterparts. For example, the theory of consumer choice postulates that the demand for a commodity is a function of the price of the commodity, the prices of related commodities and the effective income of the consumer. An experimental design consistent with this model would indicate, at least in point of principle, what real phenomena are to be identified with the theoretical specifications, what is meant by the consumer and how we could actually arrange to observe consumers making choices.

Probably the ideal method of obtaining data for estimating the demand for a commodity would be to conduct an elaborate experiment wherein the reactions of consumers to alternative prices and levels of income would be tabulated. On the basis of the set of observations generated by this scheme and the assumed known form of the function connecting the variables, it is possible to estimate the parameters of the functional relationship

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[5] T. Haavelmo, "The Probability Approach in Econometrics," Supplement to Econometrica, Vol. 12, 1944, pp. 5-7.

and the parameters of the distribution of the residuals. These estimates and the attendant prediction of consumer behavior may be obtained by two distinct procedures. Marschak has discussed these procedures as follows:

> "...I shall call the two procedures the specific experiment and the general experiment. Examples of specific experiments and the testing of model bridges or the testing of aerodynamic tunnels. Here the experiment consists in reproducing the specific structural change whose effect one wants to predict. The original structure is not the subject of investigation. General experiments on the other hand are designed not to predict the results of a single specific structural change, but to make possible the prediction of the results of any possible structural change. Experiments made in physical laboratories to establish fundamental laws of physics or chemistry are of this kind. The time required to boil an egg can be estimated by boiling eggs, but in principle it can also be estimated by studying first the general properties of protein molecules, in which case not only the answer to the egg boiling question, but of many other questions as well, will be prepared."[6]

The use of controlled experiments in economic research then, requires that the investigator have sufficient control of the variables to conduct either general experiments or specific experiments. The difficulties inherent in general experimentation have done much to promulgate the estimation of the structural parameters with non-experimental techniques. Experimentation with economic phenomena appears more feasible via the specific experiment and the estimation of conditional relationships.

B. Specific Problem Areas

The major objective of this research was to study the effectiveness of controlled experiments in generating data on consumers' response to

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[6] J. Marschak, "Statistical Inference from Non-Experimental Observations: An Economic Example," Proceedings of the International Statistical Conference, 1947, Vol. III, p.292.

prices of three food products under conditions approximating those imposed by static economic theory. Each product was studied by means of a separate experiment.

The following were the objectives of the experiment for eggs:

(1) Estimation of a short-run price-consumption relationship for eggs aggregated over grades,

(2) Estimation of short-run price-consumption relationships for eggs by grades,

(3) Estimation of consumer preference for eggs when all grades are priced alike, and

(4) Estimation of the impact of consumers information, relative to grade characteristics and uses, on their choice of grades.

The following were the objectives of the experiment for T-bone steaks:

(1) Estimation of short-run price-consumption relationships for Choice grade T-bone steaks,

(2) Estimation of short-run price-consumption relationships for Good grade T-bone steaks,

(3) Estimation of short-run price-consumption relationships for the aggregate of these grades, and

(4) To ascertain whether consumers distinguish between these two grades of T-bone steak on the basis of a single physical characteristic, namely, the amount of rib-eye marbling.

The following were the objectives of the experiment for fresh fryers:

(1) Estimation of short-run price-consumption relationships for Grade A whole fresh fryers,

(2) Estimation of short-run price-consumption relationships for Grade A cut-up fresh fryers,

(3) Estimation of short-run price-consumption relationships for the aggregate of these two types of fryers, and

(4) Investigation of the changes in the structure of consumer preference for these two types of fryers under alternative levels of fryer prices.

C. Outline of the Presentation

In this introductory chapter the problem area has been delineated both generally and specifically. In addition, the importance of the role of models in quantitative economic research was discussed.

Because of the importance attached to models, Chapter II is devoted to a discussion of economic and statistical models. As an aid in model choice there is presented in this chapter a classification of variables based upon the manner in which the data are generated. This classification of variables forms the basis for the specification of a broad generalized model. Within this general model, several subclasses of models are specified and discussed with respect to their place and potential for applied economic research. Chapter II also includes a discussion of the manner in which the transition from the economic to the statistical models is made.

Following the chapter on model construction are chapters devoted to each of the commodities. Differences in choice of design and type of pricing treatments within the design were introduced as the research progressed. Experience gleaned in each phase of the study was used to improve the succeeding experiments when possible. The results are presented in the same sequence as the experiments were performed.

The chapters dealing with eggs, beef, and dressed chickens present the specific economic models, the statistical models and the experimental design to be used in obtaining parameter estimates, a description of the experimental setting, and the results obtained for each commodity.

Chapter VI presents the implications concerning the usefulness and validity of the experimental methodology in generating data for the estimation of the parameters of economic relationships.

II. CONSTRUCTION OF ECONOMETRIC MODELS

Success in the attempt to obtain quantitative estimates of behavior relationships is conditioned by the ability of the investigator to cope with the problems associated with three aspects of the estimation process: the problems connected with model construction, the problems connected with the selection or generation of suitable data, and the problems associated with the estimation technique.

In this process model construction is fundamental. The economic model represents an attempt to describe abstract relationships, among observable phenomena, conforming to some prediction criterion. The specification of a model comprising well defined hypotheses is often difficult because the underlying theories do not permit the construction of unique models. Thus, several plausible variants of any descriptive effort exist.

The transition from the economic model to an econometric model renders explicit the assumptions which form the basis upon which a quantitative investigation may proceed. When fully formulated, the econometric model specifies the nature of the variables entering each structural relation as well as the mathematical form of each relation. When the model is developed to this stage, the type of data and the manner of its generation are determined. Also, the appropriate technique for estimating and testing the parameters is determined.

The models of the present study as well as those of many earlier attempts to estimate demand relationships are based upon the theory of consumer choice.[7] This theory is founded on the premise that each consumer possesses a given set of preferences. The consumer is assumed to choose among the alternative combinations of goods and services in such a manner as to maximize his satisfaction subject to the restrictions imposed by a given set of market prices and a given level of money income available for expenditure on these items. Given these fundamental propositions, the demand relationships for each good can be derived. The transition from the demand curves of an individual for a single commodity to demand curves aggregated over individuals, commodities, and time[8] presents many problems to perplex the theoretician and hamper the application of the theory to problems of policy.

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[7]Since this research is concerned with an application rather than a restatement of the theory of consumer choice, the reader is directed to the following references for detailed treatments of the theory:

J. R. Hicks, Value and Capital, The Clarendon Press, Oxford, 1939, Chaps. 1-3.

H. Schultz, Theory and Measurement of Demand, The Chicago Press, Chicago, 1938, Chaps. 1-4.

R. T. Norriss, Theory of Consumer's Demand, Yale University Press, New Haven, 1941, Chaps. 1-10.

P. A. Samuelson, Foundations of Economic Analysis, Harvard University Press, 1948, Chap. 5.

[8]For a discussion of the problems involved and suggested approaches to these problems see:

L. R. Klein, "Macroeconomics and the Theory of Rational Behavior," Econometrica, Vol. 14, pp. 93-108.

__________, "Remarks on the Theory of Aggregation," Econometrica, Vol. 14, pp. 303-312.

K. O. May, "Technological Change and Aggregation," Econometrica, Vol. 51, pp. 51-63.

H. Theil, Linear Aggregation of Economic Relations, North Holland, Amsterdam, 1954.

Early attempts to estimate the demand relationships derived from the theory of consumer choice were based on econometric models such as the following:[9]

$$x_t = f(p_{1t}, p_{2t}, \ldots, p_{nt}, y_t; \alpha_1, \alpha_2, \ldots, \alpha_k) + u_t \qquad (2.0)$$

where x_t represents the t^{th} observation of the quantity consumed, p_{1t}, p_{2t}, ..., p_{nt} represent the corresponding prices of the n commodities in the market, y_t represents income, $\alpha_1, \alpha_2, \ldots, \alpha_k$ represent a set of parameters connecting quantity with the prices and u_t represents a residual having certain characteristic distributional properties.

The estimation of the parameters of models like (2.0) was accomplished by the use of least-squares analysis. The technique was immediately applied to the agricultural sector of the economy and demand analyses have been made for aggregates such as all farm products, all foods, food livestock products, meat animals and meats, and for many individual products.[10]

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[9] M. Gershick and T. Haavelmo, "Statistical Analysis of the Demand for Food: Examples of Simultaneous Estimation of Structural Equations," contained in Studies in Econometric Method, ed. by W. Hood and T. Koopmans, John Wiley and Sons, New York, 1953, pp. 92-93.

[10] H. Schultz, Theory and Measurement of Demand, The Chicago Press, Chicago, 1938, Chaps. 6-15.

R. W. Cox, Factors Influencing Corn Prices, University of Minnesota Agricultural Experiment Station Technical Bulletin No. 81, September, 1931.

R. W. Rudd and D. M. Schuffett, Demand Interrelationships Among Domestic Cigarette Tobaccos, Kentucky Agricultural Experiment Station Bulletin No. 633, June, 1955.

G. M. Kuznets and L. R. Klein, A Statistical Analysis of the Domestic Demand for Lemons, Giannini Foundations Agricultural Economics Report 84, processed.

In spite of the progress made through such studies many investigators became dissatisfied with the technique. Much of the dissatisfaction arose from the fact that general equilibrium theory postulated economic relationships in the form of a system of simultaneous equations whereas the empirical research being performed treated each relationship as independent of all other relationships.

In answer to this problem estimation techniques were developed which took greater recognition of the manner in which economic data are generated. Sector equilibrium models were specified with variables that influence a set of jointly determined variables yet are not influenced by them. Variables of this model are classified as endogenous variables (jointly determined within the structure) and exogenous variables (variables determined independently of the structure).

The explicit classification of variables in this fashion permitted the development of statistical methods for handling the estimation of the parameters of those sector equilibrium systems which are, in general, stochastic, dynamic, and simultaneous.

In such systems, the existence of a solution for the parameters of any particular equation become a function of the identification properties of the system; and when the structure can be cast into the form of a system of linear relations the necessary condition for the mathematical identifiability of a particular relation is given by the order condition.[11]

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[11] When a model is constructed such that G is the number of endogenous variables in the model; G* is the number of endogenous variables in the structural equation to be estimated; G** is the number of endogenous variables in the model, but not in the structural equation to be estimated; K is the number of exogenous variables in the model; K* is the number of exogenous variables in the structural equation to be estimated; and K** is the number of exogenous variables in the model, but not in the structural equation to be estimated, the order condition for identifiability is given by $K^{**} \geq G^{*} - 1$.

With these techniques, least-squares was subsumed as a special case of the more general analysis.

The problems associated with time series data have led investigators to consider controlled experiments as an alternative method of estimating the parameters of models. If such experiments would be possible, the values of the p's and of y in equation (2.0) could be taken as sets of fixed, predetermined numbers, while the observations of x would be random variables, the stochastic properties of which would be defined implicitly by the stochastic properties assumed for the u's. On the basis of a set of observations and an assumed known form of the function it would be possible to estimate the parameters, α, and the parameters of the distribution of the u's. Since the method of estimation must be consistent with the model, controlled experiments imply an alternative model type.

A. Specification of the Generalized Model

In setting up single-equation models, variables are classified generally as dependent variables, or variables whose movements are to be explained, independent variables, or variables which are related to the dependent variable and independent of one another, and error or unexplained variation remaining after the influence of the independent variables is accounted for.

Given the possibility of controlled experiments as one admissible means of generating data for economic analysis, the following formulation proved useful in specifying and classifying variables in the economic and statistical models to be presented later for eggs, steaks, and fryers.

$$y_i = f(y_{i+1}, y_{i+2}, \ldots, y_j, y_{j+1}, y_{j+2}, \ldots, y_k, y_{k+1}, y_{k+2}, \ldots, y_m, y_{m+1}, y_{m+2}, \ldots, y_n; \alpha_1, \alpha_2, \ldots, \alpha_{n+1}) \tag{2.1}$$

where y_i represents a vector or vectors of observed values of variables whose generation is to be explained; $y_{i+1}, y_{i+2}, \ldots, y_j$ represent vectors of variables whose values are experimentally controlled over some range; $y_{j+1}, y_{j+2}, \ldots, y_k$ represent vectors of variables whose values are controlled at fixed levels; $y_{k+1}, y_{k+2}, \ldots, y_m$ represent vectors of variables that are observed, but not controlled; $y_{m+1}, y_{m+2}, \ldots, y_n$ represent vectors of variables that are uncontrolled and unobserved and $\alpha_1, \alpha_2, \ldots, \alpha_{n+1}$ represent a set of unknown parameters to be estimated.

The foregoing classification of variables makes explicit the process whereby the observations are generated and points up the alternative classes of models that must be considered.

Fifteen models exist formed by all combinations of the four types of variables considered in the general model. These fifteen models may be classified as stochastic or non-stochastic. The non-stochastic models will be discussed first.

B. The Non-Stochastic Models

The non-stochastic group comprises seven models[12] each of which postulates null values for the set of parameters linking the vectors of variables whose generation is to be explained with the vectors of variables that are uncontrolled and unobserved.

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[12]With the three classifications of variables the total number of models possible is

$$\binom{3}{3} + \binom{3}{2} + \binom{3}{1} = 7.$$

Because this group of models specifies nullity of the parameters associated with variables that are uncontrolled and unobserved, perfect knowledge relative to the included variables is implied. With the present state of knowledge concerning economic behavior, it is not likely that a set of conditions exists which would permit such an exact specification of variables. In view of the small likelihood of constructing models of this type or of obtaining sufficient data consistent with the specification should it be made, the whole class of non-stochastic models has rather limited application. Consequently, attention can be directed to the alternative set, the stochastic models.

C. The Stochastic Models

1. Non-Experimental Models

By introducing non-zero values for the set of parameters connecting the variables whose generation is to be explained with the uncontrolled and unobserved variables there is created, in addition to the generalized formulation, seven stochastic models.

Consider initially the following model:

$$y_i = f(y_{k+1}, y_{k+2}, \ldots, y_m, y_{m+1}, y_{m+2}, \ldots, y_n; \alpha_{i.m}, \alpha_{i.n}) \quad (2.2)$$

where $\alpha_{i.m}$ represents the set of parameters connecting the y_i with the observed, but uncontrolled variables, $\alpha_{i.n}$ represents the set of parameters connecting the y_i with the uncontrolled and unobserved variables, and all other symbols have been defined in equation (2.1). Without additional information or assumptions the parameters of this formulation cannot be estimated. However, if a set of distributional properties are known or can be assumed for the collection of variables y_{m+1}, y_{m+2}, ..., y_n then estimates of the $\alpha_{i.m}$ may be possible.

The systems of equations research which has had widespread application in the last two decades can be viewed within this framework. Equation (2.2) can be considered as one of a system of simultaneous equations. The possibility of estimating the parameters, $\alpha_{i.m}$, is dependent upon the assumptions made concerning the uncontrolled and unobserved variables, the functional form of the relationships and the identifiability of the equation. In addition, it may be possible that the values of some subset of the observed, but uncontrolled variables are determined jointly with the y_i. If the jointly determined subset are classified as endogenous and the remainder are classified as exogenous, then estimation may proceed providing the necessary and sufficient conditions for identification are met.[13]

It is important to recognize at this point that in a model such as 2.2 there may be some subset of variables for which the range of values generated by the system is so small (in a particular sample) as to indicate that the associated subset of parameters have null values. Thus, for instance, in a retail demand equation, consumption of a particular good and its retail price may be classified as endogenous variables and income as an exogenous variable. If, in the sample, retail prices were stable, the estimated value of the associated parameter may appear to be not significantly different from zero. If the parameter in fact is not zero, the model may fail to provide sufficient information for intelligent

[13]See footnote 11.

policy decisions. Should the true parameter value be not zero, this fact could be detected by repeated sampling over a period of time sufficient to permit the variable to take on a wider range of values. When time series data are used this procedure may prove infeasible since decisions may be required in a period of time shorter than that necessary to generate a complete new sample with the desired properties.

It is also important to recognize that a model is often judged on the basis of a single sample of data. When parameter estimates indicate some subset of null values conflicting with logic, or previous well established empirical findings, either the model, the data, or both become suspect. When a new sample cannot be conveniently generated, the assessment of blame may be to the model. Consequently, an array of models may be constructed none of which appears superior to the alternatives on the basis of logical and statistical tests.

2. Experimental Models

a. Basic models

When the decision-maker cannot wait for entirely new samples of data to be generated and there is reason to suspect that the range of values for some important set of variables will be such as to result in unreliable parameter estimates, the use of one of the ensuing models may be justified. These models are classified as experimental type models since physical control over some subset of variables is specified. The simplest model of this class is given by the following formulation:

$$y_i = f(y_{i+1}, y_{i+2}, \ldots, y_j, y_{m+1}, y_{m+2}, \ldots, y_n; \alpha_{i.j}, \alpha_{i.n}) \qquad (2.3)$$

where $\alpha_{i.j}$ represents the subset of parameters connecting the y_i with the variables subject to control over some range and all other symbols have been defined in equations 2.1 and 2.2. Assuming that the uncontrolled and unobserved variables collectively act as a disturbance variable distributed normally with a mean of zero and a finite variance, then estimation of the $\alpha_{i.j}$ may be possible.

The nature of economic relationships restricts the application of this model to a rather small group of cases. Such cases arise whenever an investigator can control a sufficient number of variables over a wide enough range to make the influence of the unobserved and uncontrolled variables statistically unimportant.

This model forms the basis for a large number of experimental designs. The simplest of these is the completely randomized design. Such a design could be used by an investigator postulating that the quantity of a particular good was largely a function of the price of that good over some range. In this case the sets of variables y_i and $y_{i+1}, y_{i+2}, \ldots, y_j$ are reduced to single vectors, say, y_1 and y_{i+1} respectively. The mathematical model underlying the design can be written as:

$$y_p = m + t_p + e_p \qquad (2.4)$$

where y_p represents the observation of the quantity corresponding to the p^{th} pricing treatment, m represents the general mean, t_p represents the effect of the pricing treatment and e_p represents the collective effect of the variables $y_{m+1}, y_{m+2}, \ldots, y_n$ which is termed the experimental error.

When, in addition to price, variables such as size of display, type of packaging, or amount or type of advertizing are under experimental control, some alternative design may be applicable such as randomized blocks, latin square or perhaps an incomplete block design.

b. Covariance models

Economists rarely are able to exercise control over a sufficient number of variables and over a wide enough range to obtain statistically reliable parameter estimates. A more usual case involves, in addition to the experimentally controlled variables, one or more variables which are observed, but not subject to control by the investigator. These circumstances are expressed in the following formulation:

$$y_i = f(y_{i+1}, y_{i+2}, \ldots, y_j, y_{k+1}, y_{k+2}, \ldots, y_m, y_{m+1}, y_{m+2}, \ldots, y_n; \alpha_{i.j}, \alpha_{i.m}, \alpha_{i.n}) \quad (2.5)$$

where all symbols have been defined in equations 2.1, 2.2 and 2.3. Again, if the variables $y_{m+1}, y_{m+2}, \ldots, y_n$ are treated collectively as a random variable with certain distributional properties then estimates of the parameters $\alpha_{i.j}$ and $\alpha_{i.m}$ may be possible.

In economic research the investigator is frequently confronted with a situation in which a relatively large number of variables cannot be subjected to experimental control. For instance, in a particular problem concerning the demand for some commodity it is not possible to control the prices of all related products nor the level of income. The investigator may, however, achieve control over the price of the commodity and the prices of several related commodities. In addition, the prices of other related commodities and income may be passively observed.

The data for a model containing both the controlled variables and passively observed variables may be generated by experiments where covariance measurements are made. Thus, the prices subject to control are analagous to the treatment effects and the passively observed variables constitute a set of covariance terms. In a randomized blocks design with covariance, the statistical model may be written formally as:

$$y_{ijk} = m + t_i + b_j + \alpha(x_{ijk} - \bar{\bar{x}}) + e_{ijk} \qquad (2.6)$$

where m represents the overall mean effect, t_i represents the treatment effect, b_j represents the block effect, x_{ijk} represents the covariance element, α represents the parameter relating the x_{ijk} to y_{ijk} and e_{ijk} represents the experimental error.

Textbooks on the design and use of experiments caution that the additional observations should not be influenced by the treatments.[14] The case where the covariate is influenced by the treatments is discussed by Cochran as follows:

> "In a covariance analysis the treatment mean $\bar{y}_i$ is adjusted by the amount $-c(\bar{x}_i - \bar{\bar{x}})$. The effect of the adjustment is to change each $\bar{y}_i$ to the value that it would be expected to have if all treatments had the same x mean. It is in this way that the technique removes the effect of variations in the $\bar{x}_i$. If, however, the differences among the $\bar{x}_i$ are in part produced by the treatments, the adjustment removes part of the treatment effect and its interpretation is changed."[15]

Because of the presence of related demands, care must be exercised if the employment of price variables are to be included as covariance terms in a pricing experiment. Income is a variable more suited for use

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[14] W. G. Cochran and G. M. Cox, Experimental Designs, John Wiley and Sons, New York, 1950, p. 75.
Walter T. Federer, Experimental Design, Macmillan Co., New York, 1955, p. 484.
C. H. Goulden, Methods of Statistical Analysis, John Wiley and Sons, New York, 1952, p. 159.

[15] W. G. Cochran and G. M. Cox, op. cit., p. 82.

as a covariant since the experimenter is not in a position to manipulate consumer incomes and in small scale experiments changes in the pricing treatments are not likely to effect the level of income.

Although it may not be advisable to employ price variables as covariance terms, they cannot be excluded from an analysis without further biasing the results. Although all price variables cannot be subjected to control over some desired range, it may be possible to fix some group of them at a particular level. The relevant model in this case may be specified as:

$$y_i = f(y_{i+1}, y_{i+2}, \ldots, y_j, y_{j+1}, y_{j+2}, \ldots, y_k, y_{m+1}, y_{m+2}, \ldots, y_n; \alpha_{i.j}, \alpha_{i.k}, \alpha_{i.n}) \qquad (2.7)$$

where $\alpha_{i.k}$ represents the subset of parameters connecting the y_i with the variables whose values are controlled at fixed levels and all other symbols have been defined in equations 2.1 and 2.3.

When a distributional form can be assumed for the uncontrolled and unobserved variables and the functional form of the relationship connecting y_i with $y_{i+1}, y_{i+2}, \ldots, y_j$ can be specified, then estimates of the $\alpha_{i.j}$ may be possible. The levels at which the variables $y_{j+1}, y_{j+2}, \ldots, y_k$ are fixed are important since the values of the estimated parameters are conditional upon them. If these variables can be assigned values which are expected to persist for an extended period of time or to recur with a relatively high frequency, the limitations of the conditional relationships are not so severe. Ordinarily such conditions do not persist and the conditional relationships must be re-estimated when a sufficient period of time has elapsed to permit new fixed values to be assigned to the variables $y_{j+1}, y_{j+2}, \ldots, y_k$.

Although more complete information would be obtained concerning the response surface if a gigantic experiment could be conducted using a factorial arrangement of pricing treatments, for practical purposes the conditional approach is favored.

Two other models must be mentioned in order to complete the classification. Since they present rather trivial cases, these two formulations are presented without a discussion of their attributes. Equations (2.8) and (2.9) present the functional forms of these remaining models.

$$y_i = f(y_{j+1}, y_{j+2}, \ldots, y_k, y_{k+1}, y_{k+2}, \ldots, y_m, y_{m+1}, y_{m+2}, \ldots, y_n; \alpha_{i.j}, \alpha_{i.k}, \alpha_{i.n}) \quad (2.8)$$

$$y_i = f(y_{j+1}, y_{j+2}, \ldots, y_k, y_{m+1}, y_{m+2}, \ldots, y_n; \alpha_{i.k}, \alpha_{i.n}) \quad (2.9)$$

where all symbols have been defined in equations (2.2) and (2.7).

Which of the above formulations would be the most useful in analyzing a particular problem will depend upon the investigator's knowledge and assumptions concerning the nullity of each of the parameters $\alpha_1, \alpha_2, \ldots, \alpha_{n+1}$ in the general model.

The general model, with its attendant classification of variables, serves to reduce an innumerable set of alternative formulations to a manageable set. The classification of the variables presented in this chapter brings into sharp relief the manner in which the observations are generated and unites in a single formulation the alternative experimental and non-experimental models.

The subset of non-stochastic models appear, with the present level of knowledge, to be of extremely limited value for the social sciences. Among the stochastic set, model (2.2) which can be considered as the foundation for the systems of equations models, is consistent with economic theory, but has the drawback that the variables may not vary over a wide enough range to permit reliable parameter estimates to be obtained. In certain instances, particularly short-run problems at the retail level, the set of experimental models may offer a feasible alternative. Should sound techniques be devised for combining the results of short-run and longer-run analyses, the experimental models may combine with the non-experimental models to provide information for improved decisions.

D. Comments on Aggregation and Measurement

Prior to concluding this chapter it may be advantageous to digress briefly on the topics of aggregation and measurement. These two topics give rise to many unsolved problems of estimation influencing the choice of model.

1. Aggregation Problems

Consider first the influence of aggregation. The general model may be considered in terms of micro-variables. Thus, the micro-variables specify a model which involves a system of i equations. Interest, however, may not center on the movements of any of the individual y_i. Through aggregation, the first k variables might be reduced to a single variable, y_1', and similarly the variables y_{k+1}, y_{k+2}, ..., y_m might also be reduced to a single variable of interest, y_2'. Therefore, in this instance, when aggregation is feasible and interest is centered on two aggregates, the number of equations necessary for a complete model is reduced from i to two. If these two aggregates form magnitudes which are meaningful for decision purposes and which can be related in functional form, then parameter estimates may be possible at a smaller cost.

Aggregation among the variables that are controlled over some range is an important factor since, even were it possible to obtain control over most of the variables of a Walrasian type model, the appropriate design of experiment and the corresponding computations would doubtless be unmanageable.

As an example, consider a problem concerned with estimating the effects of a good on the consumption of that good. This problem might be handled by employing one of the balanced lattice squares where the squares might represent given levels of prices for all other goods; the rows of each square might represent individual retail outlets; the columns of each square might represent the time duration of any particular treatment; and the various prices of the commodity of interest constitute the treatments which are assigned positions within the squares according to the particular lattice chosen. If, however, the retail outlets can be aggregated in some fashion into a single unit then a solution may proceed in terms of the analysis of a randomized blocks design with considerable savings in time and effort.

Similarly, if the observed, but uncontrolled variables can be aggregated then the number of covariance adjustments may be reduced accordingly. It must be emphasized that aggregation should yield variables that are meaningful for decision purposes.

2. Measurement Problems

Although the measurement effects are discussed separately from the aggregation effects, the two jointly affect the final model choice.

In any quantitative research one important problem is whether measurement in any sense is at all possible. A model may, for instance, have been specified which contains variables defined so as to defy measurement. More commonly, perhaps, measurement is restricted by legal or institutional factors. Difficulties in generating measurable quantities economically may form an additional restriction.

When the set of parameters $\alpha_{i.n}$ have values greater than zero, but there are restrictions on the measurability of the variables y_{m+1}, y_{m+2}, ..., y_n, the effect on the model is similar to incomplete specification.

Fortunately, there will usually exist for a particular analysis some set of variables for which measurement is possible. In this connection it is convenient to consider two types of measurement, cardinal and ordinal.

When a model includes variables subject to cardinal measurement, there immediately arise questions concerning errors of measurement and their effects on the parameter estimates. Within this realm three general cases occur: (1) measurement errors in the endogenous type variables, (2) measurement errors in the exogenous type variables, and (3) measurement errors in both types of variables.

When measurement errors associated with the endogenous variables are introduced the parameters of the model may be estimated by forming a new error term comprised of the original disturbance term and the elements arising from the measurement errors. Similar procedures hold for measurement errors in the exogenous variables. However, Kendall in discussing this problem states: "The errors of observation impair our estimators, vitiate our tests of significance and even bend our regression lines unless we are prepared to postulate normality in the variates...."[16]

In the analysis to be presented, measurement errors in the price variables are zero and because of the care exercised in obtaining measurements on the quantity variables such errors are assumed negligible.

Most quantitative economic models specify only cardinally measurable variables. However, many important economic variables can be measured only in an ordinal sense. The exclusion of such variables may result in large specification errors and an attendant loss in predictive power of the model.

Model builders, long aware of specification problems, have employed non-quantitative analyses to assess the impact of ordinally measurable variables on the estimates obtained from the quantitative model. Such a technique is not wholly satisfactory and a more precise means of including these variables in an analysis is desirable.

When careful attention is paid to design, experimental models permit the endogenous variables whose behavior is to be explained, to be adjusted for the effects of the ordinal variables. In view of the importance of ordinally measurable variables in economics the experimental models present an advantage that other stochastic models do not yet possess.

The preceding discussion concerning the alternative economic and statistical model formulations and the associated measurement considerations will be used in formulating the models used in each of the ensuing analyses.

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[16] M. G. Kendall, "Regression, Structure, and Functional Relationships," Biometrika, Vol. 38, pp. 23-24.

III. ANALYSIS FOR EGGS

A. The Economic Models

The economic models to be presented represent an attempt to portray, in simple form, the relationships believed to exist in the real world between consumer preferences for eggs and the monetary values placed on these preferences. Specifically, the models represent an attempt to specify short-run price-consumption relationships for eggs. Within this framework, the models are designed to explain the behavior patterns of consumers when their "basic" preferences are conditioned by changing price structures in the market or by an increased amount of information concerning a single grade factor.

In generating data reflecting the decisions of consumers, two fundamental conditions are postulated: (1) that consumers possess a set of criteria for decision-making, and (2) that consumers possess sufficient information concerning a product (though not necessarily complete information) to make the criteria operational.

With this rationale, several admissible models concerning the reactions of consumers of eggs to certain stimuli can be specified and the method by which the parameters were estimated can be discussed.

1. Preference Datum for Eggs

At the outset, a model was postulated depicting consumer preferences devoid of any relative price differences among grades. This model provided a datum for assessing the influence of a change in the amount of information presented to consumers concerning the attributes and uses of eggs. In functional form the model may be postulated as:

$$y_p = f(z_{1p}, z_{2p}, z_{3p}, z_{4p}, z_{5p}, \ldots, z_{np}; \alpha_1, \alpha_2, \ldots, \alpha_{n+1}) \quad (3.1)$$

where y_p represents the p^{th} observation on the quantity disappearance of eggs; z_{1p} represents a measure of interior quality; z_{2p} represents a measure of shell color; z_{3p}, a measure of egg size; z_{4p}, the type of carton; z_{5p}, a measure of egg cleanliness; $z_{6p}, \ldots, z_{np}$ represent measures of other preference factors; and $\alpha_1, \alpha_2, \ldots, \alpha_{n+1}$ represent a set of parameters that connect y_p with the preference factors.

Model (3.1) is conceptual and no attempt was made to estimate the parameters involved. Instead, a datum was established for the preference factor, interior quality, by recording observations of the quantity disappearance of each quality level when such factors as egg size, type of carton, and cleanliness were held constant.

Another preference factor, shell color, was investigated by offering consumers a single quality level in two shell colors while all other preference factors were held constant.

2. Consumption as Modified by Price Differentials

If consumers are to make economic decisions with respect to eggs, price must be included as a decision factor. A model describing the reactions of consumers of eggs when price is included in their set of decision-making criteria was postulated as:

$$y = f(p, z_1, z_2, \ldots, z_{n-i}; \alpha_1, \alpha_2, \ldots, \alpha_{n-i+2}) \quad (3.2)$$

where y represents the quantity disappearance of eggs summed over i grades;

p represents the average retail price of eggs; and all other symbols have been defined in equation (3.1).

Two types of pricing structures may be investigated with model (3.2). Consumer reactions to price changes in at least one grade of eggs may be measured and compared with consumer reactions when the price of all grades of eggs is changed by a uniform amount.

One of the most important factors consumers use to distinguish among eggs is interior quality as designated by grade labeling. However, consumers' affinity for this preference factor may change if the price of this factor should change. A model portraying consumers' willingness to pay for the preference factor, interior quality, was postulated as:

$$y_i = f(p_i, z_1, z_2, \ldots, z_{n-1}; \alpha_1, \alpha_2, \ldots, \alpha_{n+1}) \qquad (3.3)$$

where y_i represents the quantity disappearance of the i^{th} level of interior quality; p_i represents the retail price of the i^{th} quality level; and all other symbols have been defined in equation (3.1).

3. Consumption as Modified by Added Information

Since consumers must make decisions regarding the purchase of an extremely large number of goods and services during a limited period of time, the information possessed by the consumer relative to the attributes of many of these goods and services is likely to be meager. Although for any one commodity some consumers may possess almost perfect knowledge of the attributes, this is not likely to be true for large aggregates of consumers. A model might be constructed relating the quantity disappearance of eggs of fixed quality levels to the amount of information consumers possess about graded eggs. Since a cardinal measure of the level of information possessed by consumers is difficult, some alternative would appear desirable.

In this study, the magnitude and direction of change in consumer preferences with additional information was measured indirectly by comparing the datum (model (3.1)) with a treatment similar to the datum in all respects except that consumers received additional information concerning the attributes of graded eggs.

4. Effects of Gross Store Sales on Volume of Egg Sales

Economic theory postulates that, given a set of preferences, the demand for a good is contingent upon the price of the good, the prices of related goods, and disposable income.

Disposable income figures for consumers in a particular urban community are difficult and expensive to obtain. When such circumstances prevail a substitute variable is desirable. Gross store sales deflated by the number of store customers was selected.[17] A model describing the behavior of consumers of eggs which includes this additional variable may be postulated as:

$$y = f(p, x, z_1, z_2, \ldots, z_{n-i-1}; \alpha_1, \alpha_2, \ldots, \alpha_{n+i+2}) \qquad (3.4)$$

where x represents gross store sales deflated by the number of store customers and all other variables have been defined in equation (3.2).

If the range of quality within a good is broad enough to warrant subdivision into several subclasses or grades, then it may be expected that

[17]The use of this variable was prompted by the article "Regional Trends in Retail Trade" by Clement Winston and Marie Hertzberg which appeared in the Survey of Current Business, September 1956, p. 11-20.

changes in income will be reflected in the consumption of these various subclasses as well as for the aggregate. This situation is postulated in the following model:

$$y_i = f(p_i, x, z_1, z_2, \ldots, z_{n-2}; \alpha_1, \alpha_2, \ldots, \alpha_{n+1}) \qquad (3.5)$$

where all variables have been defined in equations (3.1), (3.3), and (3.4).

5. Changes in the Distribution of Sales Arising from a Price Change in a Single Grade

Since all subclasses of eggs are basically the same commodity, differentiated on the basis of interior quality, it is reasonable to expect some degree of competition among them. On the basis of this premise, the following model is postulated as a measure of the degree of competition among the various grades.

$$y_i = f(p_i, p_j, z_1, z_2, \ldots, z_{n-1-j}; \alpha_1, \alpha_2, \ldots, \alpha_{n+1}) \qquad (3.6)$$

where p_j represents the prices of competing grades of eggs and all other variables have been defined in equations (3.1) and (3.3).

This brief statement concludes the specification of the models to be estimated. Many alternatives and variants of those specified remain. However, the specifications presented are believed to constitute a plausible set of models.

B. The Setting

Because of the importance of the urban areas of the economy in generating demand for agricultural commodities, it is mandatory that such areas be included in a sample of data to be used in estimating the parameters of the foregoing models. It would be desirable to draw a sample from throughout the entire country, stratifying on regions, states, city size, income, family size, race and many other social and economic factors. Within the limits of available funds, such a sample was not feasible. As a less ambitious but attainable alternative, Tulsa, Oklahoma was chosen as the sampling area.

Within the city, eleven large, modern, self-service markets operating under the management of Safeway Stores were selected. The stores were located in such a manner that the sampling could take place throughout the city. These stores possessed the additional advantage of sharing a common source of supply for eggs and receiving new supplies twice weekly. Since the eggs were handled under temperature controlled conditions from the farms to the consumers and were graded and handled by a minimum of firms, an almost optimal degree of control over the quality factor was achieved.

Since all of the stores did not customarily handle the same grades and sizes of eggs, displays were standardized with respect to these two factors for the eleven stores used. Within the limits of normal store stocks and available supplies, this standardization consisted of a non-graded egg class and the three top U.S.D.A. grades (AA, A, B). These classes of eggs, in the large size only, constituted the consumers choice range for eggs in the stores sampled.

Friday and Saturday of each week for 4 1/2 consecutive weeks were selected as the test period. This selection was made for several reasons: (1) the characteristics of shoppers on Fridays and Saturdays were considered sufficiently alike to constitute a homogeneous population and permitted the effects of time within weeks to be eliminated; (2) the selection of these two days provided the location managers the remainder of the week to adjust egg stocks for overages or anticipated shortages; (3) since a substantial portion of the week's business occurs during these two days of the week (over 60 percent of egg sales), a given amount of information could be obtained at a minimum of expense and interruption of store procedure.

The eggs were displayed in refrigerated cases in accord with normal display practices except that affixed to the case in front of each grade were 5" x 9" placards designating the grade, size, and price. For the investigation of additional information the placards designated the grade, size, price and colored photographs of the top three grades in the hardcooked and the broken out form, along with a brief enumeration of the household uses for each grade. In order to minimize bias due to location of a grade within the display, the grades were rotated daily according to a randomized schedule.

For the purposes of the study permission was obtained to control the prices of eggs in the stores chosen for sampling. Pricing of the eggs was varied according to the schedule presented in Table 3.1. In choosing the prices for each grade of eggs consideration was given to the prevailing prices of eggs and to the possible harmful effects of price extremes on the relationship between Safeway Stores and their customers.

Instead of randomizing the treatments over time the ordering in Table 3.1 was employed. This assured that treatment 9 (presenting added information) would not occur prior to treatment 8 (the datum), and any possible effects of time among weeks would be further minimized for the relationships estimated for particular grades.

TABLE 3.1

PRICING TREATMENTS FOR TULSA RETAIL EGG EXPERIMENT

Treatment	Grade			
	AA	A	B	Non-Graded
1	55	48	41	36
2	62	55	48	43
3	69	62	55	50
4	62	48	41	36
5	69	48	41	36
6	69	55	41	36
7	69	62	41	36
8	55	55	55	55
9	55	55	55	55

Treatments 1 through 3 were designed to provide information on consumer responses to consecutive seven cent price increases across grades.

Treatments 1, 4 and 5 were designed to measure consumer responses to price of grade AA eggs under static conditions, while treatments 5 through 7 performed a similar function for grade A eggs.

Treatment 8 was designed to provide the data employed as a datum and treatment 9 was used to provide data for investigating the effects of added information concerning the grade and respective uses of eggs.

Regardless of the care exercised in conducting such studies, there are invariably many administrative problems arising which, unless anticipated and properly handled, tend to nullify the chances of obtaining accurate results. In order to handle some of these problems, the following procedures were employed:

Approximately one week prior to the initiation of the study all stores were contacted and briefed on the operations to be performed. A second briefing was conducted the day before the application of the first treatment. On each succeeding week, one day prior to the application of the week's first treatment, the stores were revisited to check the adequateness of supplies and distribute the price placards and record forms.

In order to prevent an inadvertent error in pricing, only information sufficient to facilitate ordering was released to store personnel in advance. In the event that supplies were not accurately anticipated and shortages appeared, liasion was maintained with the supplier and eggs were secured and delivered by supervisory personnel who maintained a daily check on displays, supplies, and records. Forms designating the proper daily rotation of egg stocks were supplied to each store as well as blank forms for recording an inventory of sales for each treatment.

C. The Statistical Model and the Design of Experiment

1. Transition to the Statistical Model

Given the models specified in section A, there is posed the problem of the type data that will best reflect the variables specified and the method whereby values for the parameters connecting the variables may be obtained. The criteria for variable classification employed in model 2.1 are useful in considering these problems.

In each of the economic models presented there appears a vector of observed values of a variable whose generation is to be explained. In addition, the cooperation of the retail chain in granting control over egg prices automatically classifies the price variables as controlled over some range.

In models 3.4 and 3.5 x was considered as an observed, but uncontrolled variable while in model 3.6 the p_j are classified as variables that are controlled at some fixed level. The remaining variables specified in the economic models were classified as uncontrolled and unobserved and values of the connecting parameters cannot be estimated. This latter group of variables was considered as a disturbance variable. If a set of assumptions are made about the distribution of the disturbance group, then the price parameters may be estimated and statistical tests performed.

With the variables classified in this manner, an examination of the economic models suggests the need for an experimental design which will isolate the price phenomena from the other influences in order that the connecting parameters may be estimated. If controlled experiments are to generate the type of data specified by present economic theory, then it is incumbent upon the economist to choose a design that will accomplish this and in the most efficient manner. The number of alternatives open to an investigator is associated with the complexity of the relationships to be estimated. Since, for any particular problem, economic theory linked with *a priori* knowledge specifies almost innumerable variables for inclusion in any given relationship, an attempt to study the relationship among a limited number of these variables requires that all other variables be subjected to the *ceterus paribus* condition by either physical or statistical control. Therefore, the choice of design will depend closely on the number of variables susceptible to control. In exploratory work care must be taken in the choice of variables to be held constant for unless there truly exist no interactions among the variates under study and those held constant, these interactions will appear in the error term.

2. The Design Used

In general, an investigator has a wide selection of alternative designs from which to choose. In any particular situation the number of alternatives narrows rapidly to a choice within a given class of designs.

In the present study retail prices of eggs were subject to control. Some degree of control existed over the grades of eggs to be offered for sale and over the stores to be included in the study. An avowed policy of the retail chain was uniform product pricing for all it's stores in a given zone of operations. Adherence to this policy involved a sacrifice of information concerning differences existing among stores.

Given control over the price of eggs and the quality levels of eggs to be offered for sale, the choice of design narrowed to a randomized block design. The use of this design defines the following statistical model:

$$y_{ijk} = m + p_i + g_j + r_k + e_{ijk}, \qquad (3.7)$$

where y_{ijk} represents the quantity disappearance of eggs in dozens per 100 customers, m represents the overall mean effect, p_i represents the price effect, g_j represents the grade effect, r_k represents the price-grade interaction, and e_{ijk} represents the experimental error.

The choice of a design as simple as that postulated above requires that several assumptions be made regarding the effects of time. Operationally, a single day constituted the smallest feasible time unit. In view of the number of treatments involved, two sources of time variation could enter the error term. The first of these, variation between days within weeks, was handled by choosing two days in which similar types of customers shopped. The second of these, variation among weeks, was uncontrolled.

At this point, two criticisms of the experimental approach to the measurement of consumer demand should be noted. The first is that with only a sample of stores cooperating in a particular area there is a possibility that with higher than average prices there is a shift in place of purchase from test to neighborhood stores. The validity of the price consumption relationship estimated, of course, suffers to the extent such shifts take place.

A second criticism arises because of the delayed and sluggish response of consumer purchases to price. Therefore, the age or length of each treatment becomes important. Experimental designs incorporating provisions for the measurement of carry-over effects offer a partial solution to this problem.

D. The Results

At the outset, emphasis is placed on the exploratory nature of the study. In this section, each of the postulated models is estimated, subjected to statistical tests, and interpreted. For each relationship estimated, it should be kept in mind that the results pertain to response relationships facing retail outlets and do not indicate what is classically thought of as the demand for a product. Also, it should be kept in mind that the results apply only to Tulsa, Oklahoma.

1. Preference Datum for Eggs

Establishment of a preference datum for eggs was accomplished by pricing all eggs alike and obtaining measurements on the quantity disappearance by grades. The results of this procedure are presented in Table 3.2 and an analysis of variance is given in Table 3.3.

TABLE 3.2

PREFERENCE DATUM FOR GRADED EGGS

	Grades[18]				
	AA	A_w	A_b	B	NG
Mean dozen sales per 100 store customers	3.77	6.34	7.40	2.65	1.95
Percent of total treatment sales	17.05	28.67	33.46	11.99	8.83

With a product graded on the basis of quality and sold without a price differential among grades, sales of the best quality may be expected to exceed sales of the alternative individual grades. For this study, when no price differential existed among grades the mean purchases of grade A significantly[19] exceeded sales of grade B and the nongraded eggs. Lack of a significant difference among all grades may imply imperfect knowledge concerning egg quality characteristics or the length of treatment may have been too short for customers to demonstrate their knowledge. On the other hand, more grades of eggs may have been offered than were warranted by the existing preference structure.

[18]The symbols AA, A_w, A_b, B, and NG represent grade AA, grade A white, grade A brown, grade B and nongraded eggs respectively.

[19]Significance is based on the results of a multiple range test presented in Table 3.3. The multiple range test is interpreted as follows: No significant difference exists among any set of underscored grade means. Thus, A_w and A_b are significantly different from B and NG, but AA is not significantly different from A_w and A_b or B and NG. For a discussion of the assumptions and computational methods see: D. B. Duncan, "Multiple Range and Multiple F Tests," Biometrika, March, 1955.

TABLE 3.3

ANALYSIS OF VARIANCE FOR PREFERENCE DATUM

Source	d.f.[20]	Sum of Squares	Mean Square	F	F_{05}	F_{01}
Total	40	399.4238				
Stores	8	95.5342	11.9418	2.55	2.29	3.23
Grades	4	173.1873	43.2968	9.27		4.07
Error	28	130.7023	4.6679			
Standard Error of Grade Mean:		1.08				
Grade Means:	(NG)	(B)	(AA)	(A_w)	(A_b)	
	1.95	2.65	3.77	6.34	7.40	

2. Effects of Price Level Changes

Treatments 1, 2, and 3 were employed to investigate the effects of changes in the price level of eggs. A seven cent differential was established among the three top grades. A five cent differential was established between grade B and nongraded eggs. A seven cent differential was used between treatments.

The results of these treatments are presented in Table 3.4 and compared with the preference datum.

Examination of the changes in percentage distribution of egg purchases among the three level treatments indicates the almost completely systematic manner in which consumers shifted from grade AA and grade A white eggs to the competing grades and then, finally, from both top quality grades to B and nongraded eggs.

[20]This analysis was based on data from nine of the stores. The total degrees of freedom are also adjusted for data obtained by missing plot technique.

TABLE 3.4

STRUCTURE OF EGG SALES UNDER ALTERNATIVE LEVELS OF PRICE

	Grades					
	AA	A_w	A_b	B	NG	Total
	(percent)					
Datum	17.05	28.67	33.46	11.99	8.83	100.00
Treatment 1	10.68	28.57	22.60	20.25	17.90	100.00
Treatment 2	8.80	24.07	29.30	21.52	16.31	100.00
Treatment 3	7.87	20.56	24.52	23.42	23.63	100.00

Alternatively, it is interesting to consider the impact of Treatments 1, 2, and 3 on egg purchases in absolute terms. Using average linear relationships, the dozens purchased per 100 customers by grades under each price are given in Figure 3.1. In constructing Figure 3.1, each relationship is considered the ordinate for the succeeding response function. In absolute terms, the relationships for grade B and nongraded eggs are completely inelastic and indicate a constant rate of purchase over the three treatments. The relationships for grade AA and grade A eggs indicate a decrease in the purchase of these grades as price increases. By summing these functions, a relationship for total egg purchases is obtained. By virtue of the nature of the relationships, a total relationship is indicated that decreases as price increases. As a basis of comparison, cumulative purchases by grades for the datum treatment are denoted in Figure 3.1 by asterisks. An analysis of variance of the data obtained in these treatments is presented in Table 3.5.

Since treatment effects were not significant no strong inferences are possible concerning the effects of seven cent changes in the level of egg prices.

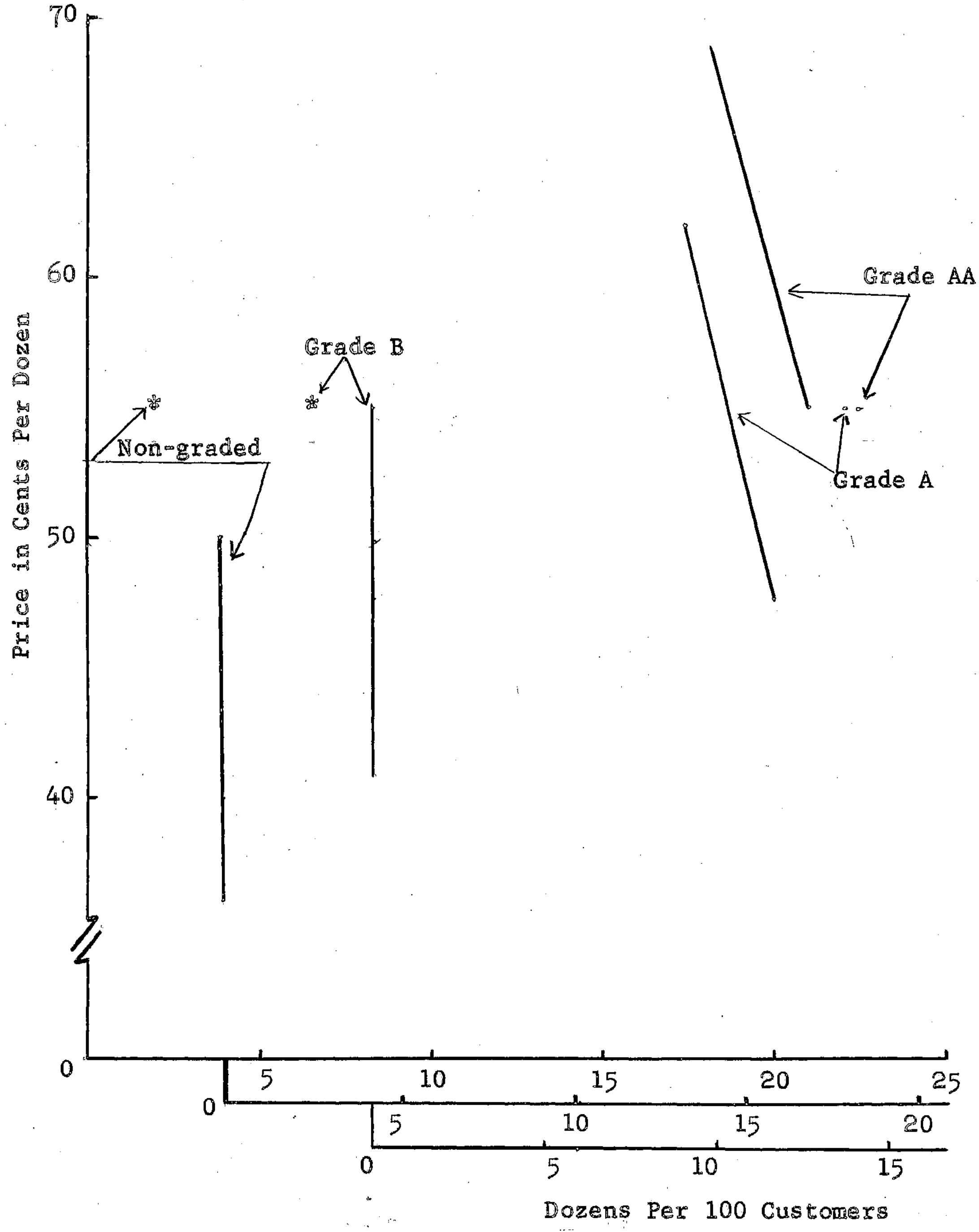

Figure 3.1 Price-Consumption Relationships for Eggs by Grades Under Three Price Level Treatments

TABLE 3.5

ANALYSIS OF VARIANCE FOR PRICE LEVEL CHANGES

Source	d.f.	Sum of Squares	Mean Square	F	F_{05}	F_{01}
Total	107	1857.0646				
Treatments	2	20.9193	10.4596	1.25	3.09	
Grades	3	991.7008	330.5669	39.53		3.98
Grade x treatment	6	41.7021	6.9503	0.83	2.19	
Error	96	802.7424	8.3619			

Standard Error of Grade Mean: 0.56

Grade Means:	AA	NG	B	A
	1.97	3.56	3.69	9.89

3. Short-Run Price Consumption Response Relationships

a. Response relationships for eggs aggregated over grades

Alternative groupings of treatments were used to obtain parameter estimates of the short-run price-consumption relationships for eggs ignoring grade differences. Initially, the situation reflected by Treatments 1, 2, and 3 was considered. Estimation of a linear model resulted in the following regression equation:

$$\hat{y}_t = 33.91 - \underset{(0.1808)}{0.2757}\, p \qquad r^2 = 0.70, \quad t = -1.52, \; t_{.05} = 12.71 \qquad (3.5)$$

where $\hat{y}_t$ represents the estimated average purchases of eggs in dozens per 100 customers and p represents the average price of eggs in cents per dozen. In this and in succeeding analyses, standard errors of estimate appear in parenthesis below the coefficient. The price elasticity of retail demand, at the means of the variables, was estimated at -0.73.

Observations generated by Treatments 1 through 7 were used as an alternative specification for the price-consumption relationship for eggs. This specification involved data generated by changes in the level of price and a change in the relative prices among grades of eggs. A linear model connecting egg purchases and price was estimated with the following result:

$$\hat{y}_t = 45.07 - \underset{(0.1072)}{0.4764}\, p \qquad r^2 = 0.80,\quad t = -4.44,\ t_{.05} = 2.57 \tag{3.6}$$

where the variables are defined as in equation (3.5). The sign of the coefficient agrees with economic logic and the price elasticity of retail demand, at the means of the variables, was estimated at -1.15.

Since past prices may be used as an additional source of information for decision-making purposes, a linear model was specified connecting average price per dozen, (p), and the change in the average price per dozen from time period d to time period d+1, (p*). This model was estimated with the following result:

$$\hat{y}_t = 45.77 - \underset{(0.1340)}{0.4829}\, p - \underset{(0.0271)}{0.0873}\, p^* \qquad R^2 = 0.93,\quad t_p = -3.60,\quad t_{p^*} = -3.22,\quad t_{.05} = 3.18 \tag{3.7}$$

This relationship reflects an estimate of the price elasticity of retail demand at the means of the variables of -1.19.

b. Price-consumption relationships by grades

In many cases, knowledge of the price-consumption relationships for eggs aggregated over grades is not sufficient. As mentioned earlier, treatments 1, 4, 5, 6, and 7 were designed to isolate the response relationships for grade AA and grade A eggs. These treatments were designed to obtain the reactions of purchasers to alternative prices for a given grade when all other prices are held constant and estimates should be interpreted with this restriction in mind.

(1) Response relationships for grade AA eggs

In order to estimate a response relationship for grade AA eggs, data generated by Treatments 1, 4, and 5 were employed. A linear model connecting purchases per 100 customers and the retail price of grade AA eggs was estimated with the following result:

$$\hat{y}_{aa} = 6.70 - \underset{(0.0136)}{0.0693}\, p_{aa} \qquad r^2 = 0.96, \quad t = -5.09, \ t_{.05} = 12.71 \qquad (3.8)$$

where $\hat{y}_{aa}$ represents the estimated quantity disappearance of grade AA eggs in dozens per 100 customers and p_{aa} represents the retail price of grade AA eggs in cents per dozen. Based on this relationship, a point estimate of the price elasticity of retail demand of -1.78 was obtained. Although the study was not designed to ascertain the degree of competition among grades of eggs, the data generated by these three treatments indicated that an insignificant substitution of grade A eggs for grade AA eggs may have occurred as the price of the latter increased. Table 3.6 presents the percentage distribution of egg sales for these three treatments.

TABLE 3.6

DISTRIBUTION OF EGG SALES UNDER VARYING PRICE FOR GRADE AA EGGS; CONSTANT PRICES FOR OTHER GRADES

	Grade				
	AA	A	B	NG	Total
	(percent)				
Treatment 1	10.68	51.17	20.25	17.90	100.00
Treatment 4	9.39	54.06	19.10	17.45	100.00
Treatment 5	9.20	54.57	20.70	15.55	100.00

Although it cannot be considered a demand relationship in the Marshallian sense an estimate of the response relationship for grade AA eggs generated by Treatments 1, 2, and 3 is presented. It should be noted that the prices of all other grades were not held constant as in the previous analysis. Applying this data to a linear model resulted in the following regression equation:

$$\hat{y}_{aa} = 6.43 - \underset{(0.0107)}{0.0729}\, p_{aa} \qquad r^2 = 0.98,\quad t = -6.81,\ t_{.05} = 12.71 \qquad (3.9)$$

where all variables have been defined in equation 3.8. It is interesting to note the similarity in the point estimates of the coefficients connecting price and quantity in equations 3.8 and 3.9.

(2) Response relationships for grade A eggs

As the basis for estimating a response relationship for grade A eggs, data generated by Treatments 5, 6, and 7 were employed. A linear model was estimated which resulted in the following regression equation:

$$\hat{y}_{a} = 22.62 - \underset{(0.0388)}{0.2286}\, p_{a} \qquad r^2 = 0.97,\quad t = 5.89,\ t_{.05} = 12.71 \qquad (3.10)$$

where $\hat{y}_a$ represents the estimate of the quantity disappearance of grade A eggs in dozens per 100 customers and p_a represents the retail price of grade A eggs in cents per dozen. A point estimate of the price elasticity of retail demand of -1.25 resulted. An inspection of the changes in the percentage distribution of egg sales for these treatments (Table 3.7) suggests some substitution of grade B and nongraded eggs for grade A eggs. Inasmuch as the response to price of grade A eggs was not statistically significant, such shifts appear negligible.

As in the case of grade AA eggs, a relationship for grade A eggs was estimated using the data generated by Treatments 1, 2, and 3. Again, attention is called to the fact that the prices of other grades were not held constant in these treatments. A linear model was estimated with the following result:

$$\hat{y}_a = 24.57 - \underset{(0.2078)}{0.2751}\, p_a \qquad r^2 = 0.60 \quad t = -1.24,\ t_{.05} = 12.71 \tag{3.11}$$

where all variables have been defined in equation 3.10. A point estimate of the retail price elasticity of -1.17 resulted.

TABLE 3.7

DISTRIBUTION OF EGG SALES UNDER VARYING PRICE FOR GRADE A EGGS; CONSTANT PRICES FOR OTHER GRADES

	Grade				
	AA	A	B	NG	Total
	(percent)				
Treatment 5	9.20	54.57	20.70	15.55	100.00
Treatment 6	8.38	48.21	22.73	20.68	100.00
Treatment 7	5.49	46.20	24.68	23.63	100.00

(3) Response relationship for grade B and nongraded eggs

Although the study was not designed specifically to measure a response relationship for grade B and nongraded eggs the data generated by the experiment was used to obtain an estimate of this relationship. Since there is some indication that grade A eggs substitute, though perhaps insignificantly, for grade B and nongraded eggs their price was included in this relationship which is based on more degrees of freedom than the relationship in equation 3.10. Estimation of a linear model connecting the quantity disappearance of grade B and nongraded eggs with the average price of grade B and nongraded eggs and the price of grade A eggs resulted in the following regression equation:

$$\hat{y}_b = 8.49 - \underset{(0.0627)}{0.1680}\, p_b + \underset{(0.0548)}{0.1380}\, p_a \qquad \begin{array}{l} R^2 = 0.67 \\ t_{pb} = -2.68 \\ t_{pa} = +2.52 \\ t_{.05} = 2.77 \end{array} \qquad (3.12)$$

where $\hat{y}_b$ represents the estimated quantity disappearance of grade B and nongraded eggs in dozens per 100 customers, p_b represents the average retail price of grade B and nongraded eggs, and p_a is defined in equation 3.10. Although the estimate of the connecting parameter approached significance no strong inference can be made regarding the influence of the price of grade A eggs on the quantity disappearance of grade B and nongraded eggs. Use of this relationship yielded a point estimate of elasticity of -0.8125 and a point estimate of cross elasticity of 0.8205.

4. Impact of Consumer Information on Choice

In most cases the choices of consumers in the market are restricted by imperfect information relative to the attributes of a product. In order to investigate this imperfection, during Treatment 9, additional information was supplied to shoppers concerning the quality attributes and best uses for each grade of eggs. Although a more complex experimental design would be needed to adequately investigate this area, it was hoped that this simple effort might provide an insight into the impact of level of information on choice. The data generated by Treatment 9 is compared with the data of Treatment 8 in Table 3.8.

TABLE 3.8

IMPACT OF LEVEL OF INFORMATION ON CHOICE

	Grade				
	AA	A	B	NG	Total
			(percent)		
Treatment 8 (datum)	17.05	62.13	11.99	8.83	100.00
Treatment 9 (added information)	22.18	57.48	11.66	8.68	100.00
Net percent movement	+5.13	-4.65	-0.33	-0.15	0.00

Although caution should be exercised in drawing inferences from these data, the results do indicate that, in the period studied, consumers with additional knowledge tended to shift their consumption pattern to higher quality eggs. The data suggest a shift from grade A to grade AA eggs may have occurred. An analysis of variance for this treatment given in Table 3.9 indicates that the magnitudes of the shifts are not significant to a degree to distinguish it from the datum. This is one area where the age of the treatment is probably of great importance. There is undoubtedly some "stickiness" between information and choice.

5. Impact of Income on Sales

In section A.4 the desirability of an income variable and the difficulty associated with obtaining such a variable were discussed. For this study, gross store sales were considered as a possible alternative.

a. Eggs aggregated over grades

Employing a linear model, average gross store sales per 100 customers was entered as an income variable with the following result:

TABLE 3.9

ANALYSIS OF VARIANCE (ADDED INFORMATION)

Source	d.f.	Sum of Squares	Mean Square	F	F_{05}	F_{01}
Total	31	1111.1732				
Stores	7	189.1719	27.0245	3.47	2.49	3.65
Grades	3	758.4130	252.8043	32.45		4.87
Error	21	163.5883	7.7899			

Standard Error of Grade Mean: 1.61

Grade Means:	(NG)	(B)	(AA)	(A)
	2.17	2.94	5.78	14.44

$$\hat{y}_t = 54.66 - \underset{(0.0544)}{0.5170}\, p - \underset{(0.1759)}{0.0169}\, s \qquad R^2 = 0.80,\quad t_p = -9.50,\quad t_s = -0.09 \quad t_{.05} = 2.77 \tag{3.13}$$

where s represents the average gross store sales per 100 customers and all other variables have been defined in equation 3.5.

The magnitude of the coefficient of s indicates that, for a commodity such as eggs, the income effect as measured by average gross store sales per 100 customers is so small as to be negligible.

b. Grade AA and grade A

In order to ascertain if the income variable might be associated with grade, average gross store sales were introduced into the response relationships for grades AA and A. The results for grades AA and A are presented in equations 3.14 and 3.15 respectively.

$$\hat{y}_{aa} = 17.68 - \underset{(0.0222)}{0.1308}\, p_{aa} - \underset{(0.1548)}{0.0163}\, s \qquad R^2 = 0.70,\quad t_{paa} = -5.89,\quad t_s = -0.10,\quad t_{.05} = 2.77 \tag{3.14}$$

$$\hat{y}_a = 12.61 - \underset{(0.0394)}{0.2384}\, p_a + \underset{(0.0506)}{0.0241}\, s \qquad \begin{array}{l} R^2 = 0.80 \\ t_{pa} = -6.05 \\ t_s = +0.48 \\ t_{.05} = 2.77 \end{array} \qquad (3.15)$$

where all variables have been defined in equations 3.8, 3.9, and 3.13.

As in the case of eggs aggregated over grades, gross store sales as a measure of income failed to contribute significantly to an explanation of the quantity disappearance of these two grades of eggs. Additional sampling would seem to be warranted to assess the value of gross store sales as a measure of income.

These two relationships provide alternative estimates of the price elasticity for each of these two grades of eggs. For grade AA eggs an estimate of -4.43 was obtained; and for grade A eggs an estimate of -1.23 was obtained.

IV. ANALYSIS FOR BEEFSTEAK

The potential of controlled experiments as a method of generating data for the estimation of price-response relationships cannot be adequately evaluated on the evidence provided by a single trial. Therefore, consideration is now given to the feasibility of employing the experimental technique to generate price-response relationships for beefsteak. Such consideration will proceed by postulating a set of economic models and investigating the nature of the variables specified therein.

A. The Economic Models

The economic models to be presented represent an attempt to specify in simple form, the short-run price-consumption relationships for T-bone steaks. As such, the models are designed to explain the behavior patterns of an aggregate of consumers when their choices are conditioned by alternative types of price changes in the market. The selection of the admissible models is conditioned by the state of knowledge concerning the behavior patterns of steak purchasers as well as the lack of any set of criteria permitting a choice among the competing alternative models. Therefore, as with the models for eggs, the models for T-bone steak are postulated on the basis of economic theory.

1. Price-Response for T-bone Steaks Aggregated Over Grades

For T-bone steak, as with many other products, price may be expected to be an important variable involved in the consumer decision process. A model describing the relationship between consumption and price may be postulated as:

$$y = f(p, z_1, z_2, \ldots, z_{n-i}; \alpha_1, \alpha_2, \ldots, \alpha_{n-i+2}) \quad (4.1)$$

where y represents the quantity disappearance of T-bone steaks, p represents the average retail price of T-bone steaks, $z_1, z_2, \ldots, z_n$ represent vectors of other preference factors such as thickness of the steak, relative amount of lean to bone, etc, and $\alpha_1, \alpha_2, \ldots, \alpha_{n-i+2}$ represent a set of parameters to be estimated.

2. Price Response for Individual Grades

As was the case with eggs, an important factor used by consumers to distinguish among steaks is the quality as measured by some grading system. Again, consumers' affinity for this preference factor may change if the price of this factor should change. In addition, the change in affinity may be related to the manner in which the prices change. A model portraying consumers' willingness to pay for the factor, steak quality, may be postulated as:

$$y_i = f(p_i, p_j, z_1, z_2, \ldots, z_n; \alpha_1, \alpha_2, \ldots, \alpha_{n+3}) \quad (4.2)$$

where y_i represents the quantity disappearance of the i^{th} quality of T-bone steak, p_i represents the retail price of the i^{th} grade, p_j represents the retail prices of competing grades of T-bone steak, and all other variables have been defined in equation 4.1.

This model can be used to investigate the nature of the response relationships under two alternative types of price change. The first of these consists of a price change for the i^{th} grade when prices of other grades are held constant. The second consists of a uniform price change for all grades of T-bone steak.

B. The Setting

A large metropolitan market was desired because of the importance of such markets as reflectors of consumer demand. Tulsa, Oklahoma, was chosen as the sampling area. This choice permitted closer supervision of the experiment than could have been achieved if smaller markets in several cities had been sampled.

Eight large, modern, self-service markets operating under the management of Safeway Stores were selected within the city. The stores were located in such a manner that the sampling could take place throughout the entire city. The stores were located far enough apart that, with higher than average prices, a shift in place of purchase from one test store to another was not likely to occur. Of course, the possibility remains that under the above pricing condition, some degree of shift may occur from test to neighboring stores.

Many other alternative courses of action were also available to consumers, but it was assumed that the income effect of alternative action with respect to a single cut of beef would lead to a substitution of some other cut of beef or some other type of meat within the test store.

Thursdays, Fridays and Saturdays of each week for three consecutive weeks were selected as the test period. Such a selection made it possible to shorten the test period to a point where it more nearly approximated a static situation. At the same time, since the bulk of meat purchases are made on these three days, a given amount of information could be obtained at a minimum of expense and interruption of store procedure. By using only three days of a week as a test period, location managers were provided with some opportunity to adjust their stocks for surpluses or anticipated shortages.

In the recent past, consumers of beef in the Tulsa market have had to choose mainly between the two federal grades, Choice and Good. For this reason the T-bone cut from competing grades was not included in this study. Choice and Good grade steaks were trimmed to a uniform thickness of external fat cover and displayed side by side in the self-service counter. For the duration of the experiment, grade information was omitted from the package label. To eliminate biases arising from the position of a particular grade in the display, each grade was assigned a position at random for each store during each treatment period.

Pricing of the steaks followed the schedule of treatments presented in Table 4.1. The treatments were randomized according to the design presented in Table 4.2.

TABLE 4.1

PRICING TREATMENTS IN CENTS PER POUND, FOR T-BONE STEAK EXPERIMENT OF CHOICE AND GOOD GRADES

Treatment	Choice	Good
1	115	115
2	95	95
3	75	75
4	135	115
5	115	95
6	95	75
7	95	115
8	75	95
9	115	75

TABLE 4.2

RANDOMIZATION OF PRICING TREATMENTS FOR TULSA T-BONE STEAK EXPERIMENT, FEBRUARY, 1957

Day	Store Code Number 1	2	3	4	5	6	7	8
February 7	t_8	t_7	t_6	t_4	t_1	t_2	t_9	t_3
February 8	t_9	t_3	t_7	t_2	t_8	t_5	t_6	t_4
February 9	t_7	t_2	t_1	t_8	t_9	t_6	t_4	t_5
February 14	t_3	t_8	t_2	t_6	t_5	t_1	t_7	t_9
February 15	t_1	t_5	t_8	t_3	t_4	t_9	t_2	t_6
February 16	t_4	t_6	t_9	t_5	t_3	t_8	t_1	t_7
February 21	t_5	t_9	t_4	t_1	t_6	t_7	t_3	t_2
February 22	t_2	t_4	t_5	t_9	t_7	t_3	t_8	t_1
February 23	t_6	t_1	t_3	t_7	t_2	t_4	t_5	t_8

Treatments 1 through 3 were designed to measure the effects of uniform price level changes on the total consumption of T-bone steaks and on the relative consumption of the two grades.

Three sets of treatments were designed to measure the response of consumers of Choice grade T-bone steaks to price. Treatments 1, 4, and 7 were designed to measure this relationship when Good grade T-bone was priced at $1.15 per pound. Treatments 2, 5, and 8 provided the data for a similar relationship when Good grade was priced at $0.95 per pound and Treatments 3, 6, and 9 performed a comparable role when Good grade was priced at $0.75 per pound.

Two sets of treatments provided estimates of the price-response relationships for Good grade T-bone steak at fixed price levels of Choice grade steaks. Treatments 1, 5, and 9 were designed to accomplish this when Choice steaks were priced at $1.15 per pound. Treatments 2, 6 and 7 were designed to estimate a similar relationship when Choice steaks were priced at $0.95 per pound.

Several days prior to the initiation of the experiment, each of the stores was contacted. At this meeting, the purpose of the study and the role of the store in setting up the displays and collecting the data under the specified conditions was explained to the meat manager.

A second meeting was held on the day preceding the application of the first treatment. Thereafter, a visit was made to each store on each treatment day to insure the adequacy of the display with respect to appearance, proper display of grades and proper treatment prices. As records of previous treatments were collected, they were checked for completeness and possible gross errors.

C. The Statistical Model and the Design of Experiment

1. Transition to the Statistical Model

Given the model postulated in the preceding section the nature of the variables specified must be investigated to ascertain the feasibility of employing one of the experimental designs to generate the requisite data for parameter estimation. The criteria for variable classification employed in model 2.1 are useful in considering these problems.

In each of the economic models presented, there appears a vector of observed values whose generation is to be explained. In addition, with the present state of knowledge, it is unlikely that all of the variables influencing the values of the vector y can be specified and/or observed. Therefore, some set of variables, say, z_m, ..., z_n can be classified as uncontrolled and unobserved. Specifying such conditions for the above models, stochastic relations are formed and the possibility of estimation turns on the classification of the remaining set of variables and the distributional properties assumed for the uncontrolled and unobserved z's.

The control over price granted by the retail chain permits the price of T-bone steaks to be classified as a variable subject to control over some range. The variables z_1, z_2, ..., z_m were classified as a set of variables controlled at some fixed level. Similarly, in model 4.2 consider p_i as a variable controlled over some range, while p_j, z_1, z_2, ..., z_m are variables controlled at fixed levels.

With the variables classified in this manner, a model such as 2.7 is specified. The particular statistical model and an associated experimental design are determined by the number of variables that must be brought under the ceterus paribus restriction by statistical control.

2. The Design Used

The restrictions imposed by the economic models and by the particular classification of variables imply the use of a statistical model within the framework of an experimental design. In addition, restrictions on the number of stores available for sampling and on the number of days during which the study could be conducted led to the postulation of the following statistical model used in the generation of the data:

$$y_{ijk} = m + d_i + s_j + p_k + e_{ijk} \qquad (4.3)$$

where y_{ijk} represents the quantity disappearance of T-bone steak in pounds per 1,000 customers; m represents the overall mean effect; d_i represents the day effects; s_j represents the store effects; p_k represents the price effects; and e_{ijk} represents the experimental error. When $i = 1, 2, \ldots, n$; $j = 1, 2, \ldots, n$; $k = 1, 2, \ldots, n$, this model represents the familiar latin square design. In this study, however, $i = 1, 2, \ldots, 9$; $j = 1, 2, \ldots, 8$; and $k = 1, 2, \ldots, 9$. Model 4.3 is descriptive then, of an incomplete block design and e_{ijk} represents the intrablock error. As with most other designs, e_{ijk} is assumed to be distributed normally and independently with mean zero and variance σ^2.

D. The Results

1. Results for T-bone Steaks Aggregated Over Grades

In order to use a simple static economic model, the data were adjusted for variations introduced by differences in the stores, days within weeks, and between weeks. These adjustments were accomplished through an analysis of variance.[21]

a. The analysis of variance

The results of the analysis of variance for the aggregate of T-bone steaks are presented in Table 4.3. Price (over the range studied) significantly affected the purchases of T-bone steaks. The importance of environmental conditions is pointed up by the magnitude of the mean squares for stores.

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[21] For a discussion of the analysis of variance for the design employed, see W. G. Cochran and G. M. Cox, Experimental Designs, John Wiley and Sons, 1950, p. 370-390.

Included in Table 4.3 is a multiple range test[22] for treatments at the 1 percent probability level. This test indicates that when the average price of T-bone steaks ranged from 85 cents per pound to 115 cents per pound, no significant change in T-bone purchases per 1,000 customers occurred. At an average price of 125 cents per pound, however, a significant decrease in purchases resulted. At an average price of 75 cents per pound a significant increase in purchases occurred. These results are consistent with the underlying static economic theory.

TABLE 4.3

ANALYSIS OF VARIANCE FOR AGGREGATE T-BONE STEAKS

Source of Variation	d.f.	Sums of Squares	Mean Square	F	F_{01}
Total	67	20,184.566			
Stores	7	6,059.862	865.694		
Days	8	1,310.738	116.467		
Treatments (adjusted for days)	8	8,011.445	1,001.431	9.17	2.94
Error	44	4,802.520	109.148		

Standard Error of a Treatment Mean = 3.69
Treatment Means (adjusted for days)

t_4	t_7	t_1	t_5	t_2	t_9	t_6	t_8	t_3
16.06	19.70	25.22	25.73	27.10	28.88	34.59	39.90	53.39

[22]See footnote 19.

b. Response relationships

Economists and businessmen will agree that, for most goods, the above results are to be expected. Interest centers on the manner in which price and sales are related, since the percentage change in quantity resulting from a percentage change in prices may significantly affect a firm's total revenue. One of the simplest formulations postulates a relationship between quantity purchased and average price that is linear in logarithms.[23] The quantified results of such a formulation, using all nine treatments, are presented in Equation 4.4.[24]

$$\hat{y} = 5.61 - \underset{(0.30)}{2.09}\, p \qquad r^2 = 0.87 \quad t = 6.97 \quad t_{.05} = 2.36 \qquad (4.4)$$

where $\hat{y}$ represents the logarithm of the aggregate sales of T-bone steaks in pounds per 1,000 customers and p represents the logarithm of the average price of T-bone steaks in cents per pound. This relationship indicates that 87 percent of the variation in T-bone purchases can be explained by variations in the average price of T-bone steaks. The negative sign accompanying the coefficient is consistent with logic in that the price and consumption of T-bone steaks are inversely related. With an equation in logarithmic form, the coefficient represents an estimate of the elasticity of retail demand and may be interpreted to mean that a 1 percent rise (decrease) in the average price of T-bone steaks results in a 2.09 percent decrease (increase) in quantity purchased per

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[23] With a product such as T-bone steak, the response to price, over the ranges studied, may very likely be curvilinear. With so few degrees of freedom for fitting, a transformation to logarithms was used.

[24] In this and in succeeding analysis, standard errors of estimate appear in parenthesis below the coefficient.

1,000 customers.

Expenditures for T-bone steaks possibly varied from treatment to treatment, although total income was assumed constant over the short time period studied. To approximate this income effect, average meat sales in dollars per 1,000 customers were entered in the logarithmic equation as an additional variable. The results of such a formulation using all nine treatments are presented in Equation 4.5.

$$\hat{y} = 2.38 - \underset{(1.02)}{2.23}\, p + \underset{(1.09)}{1.11}\, i \qquad \begin{array}{l} R^2 = 0.90 \\ t_p = -2.18 \\ t_i = 1.02 \\ t = 2.45 \end{array} \qquad (4.5)$$

where i represents the logarithm of meat sales in dollars per 1,000 customers and all other variables have been defined in equation 4.4. This relationship leads to a slightly greater estimate of retail price elasticity than was obtained from equation 4.4. The meat sales coefficient is statistically insignificant and consequently contributes little to an explanation of the effect of "income" changes on T-bone sales.

2. Results for Choice Grade T-bone Steaks

When a product can be subclassed according to some grading standards, it is desirable to estimate the effects of price on each grade.

a. The analysis of variance

To isolate the effects of price on the sales of Choice grade T-bone steaks, an analysis of variance was made to remove the variation due to stores and to adjust the data for differences due to time. The results of the analysis are presented in Table 4.4.

The analysis of variance for Choice grade T-bone steaks is analogous to that for the aggregate T-bone analysis in that the two important sources of variation were associated with locational factors and pricing treatments.

TABLE 4.4

ANALYSIS OF VARIANCE FOR CHOICE GRADE T-BONE STEAKS

Source of Variation	d.f.	Sum of Squares	Mean Square	F	$F_{.01}$
Total	67	8216.768			
Stores	7	1773.589	253.370		
Days	8	700.415	87.551		
Treatments (adjusted for days)	8	2666.945	333.368	4.77	2.94
Error	44	3075.818	69.905		

Standard Error of a Treatment Mean = 2.96

Treatment Means

t_4	t_9	t_6	t_5	t_2	t_1	t_7	t_8	t_3
6.75	9.40	10.23	11.59	14.78	15.17	16.35	24.92	25.23

The multiple range test for Choice grade T-bone steaks is not as easy to interpret as the test for Good grade steaks because each treatment mean is unadjusted for the affects of the competing grade of steak. However, if Treatments 4, 1, and 7 are compared (i.e. where the price of Good is constant at 115 cents per pound) it is evident that as the price of Choice declines, sales increase. A similar situation occurs for Treatments 5, 2, and 8 where the price of Good is constant at 95 cents per pound and for Treatments 9, 6, and 3 where the price of Good is constant at 75 cents per pound.

b. Response relationships

A simple model, linear in logarithms, was used to estimate the parameters connecting price and sales of T-bone steaks. A separate relationship was estimated for each of the price levels of Good grade steaks. Equation 4.6 presents the estimated relationship connecting price and sales of Choice grade steaks over a range of 135 cents per pound to 95 cents per pound when Good grade steaks were priced at 115 cents per pound (Treatments 1, 4, and 7). Equation 4.7 presents a similar relationship covering a price range from 115 cents per pound to 75 cents per pound when Good grade was priced at 95 cents per pound (Treatments 5, 2, and 8). Equation 4.8 presents a relationship covering the 115-75 cent price range for Choice when Good was priced at 75 cents per pound (Treatments 9, 6, and 3).

$$\hat{y}_c = 6.11 - \underset{(1.33)}{2.45}\, p_c \qquad r^2 = 0.77,\quad t = -1.84,\quad t_{.05} = 12.71 \tag{4.6}$$

$$\hat{y}_c = 4.77 - \underset{(0.27)}{1.81}\, p_c \qquad r^2 = 0.98,\quad t = -6.70,\quad t_{.05} = 12.71 \tag{4.7}$$

$$\hat{y}_c = 5.80 - \underset{(0.96)}{2.37}\, p_c \qquad r^2 = 0.86,\quad t = -2.47,\quad t_{.05} = 12.71 \tag{4.8}$$

where $\hat{y}_c$ represents the logarithm of the quantity disappearance of Choice grade T-bone steaks in pounds per 1,000 customers and p_c represents the logarithm of the price of Choice grade T-bone steaks in cents per pound.

In each instance the sign of the coefficient agrees with the economic logic that as the price of a good rises the consumption decreases. A graphical presentation (Figure 4.1) of these relationships, converted from

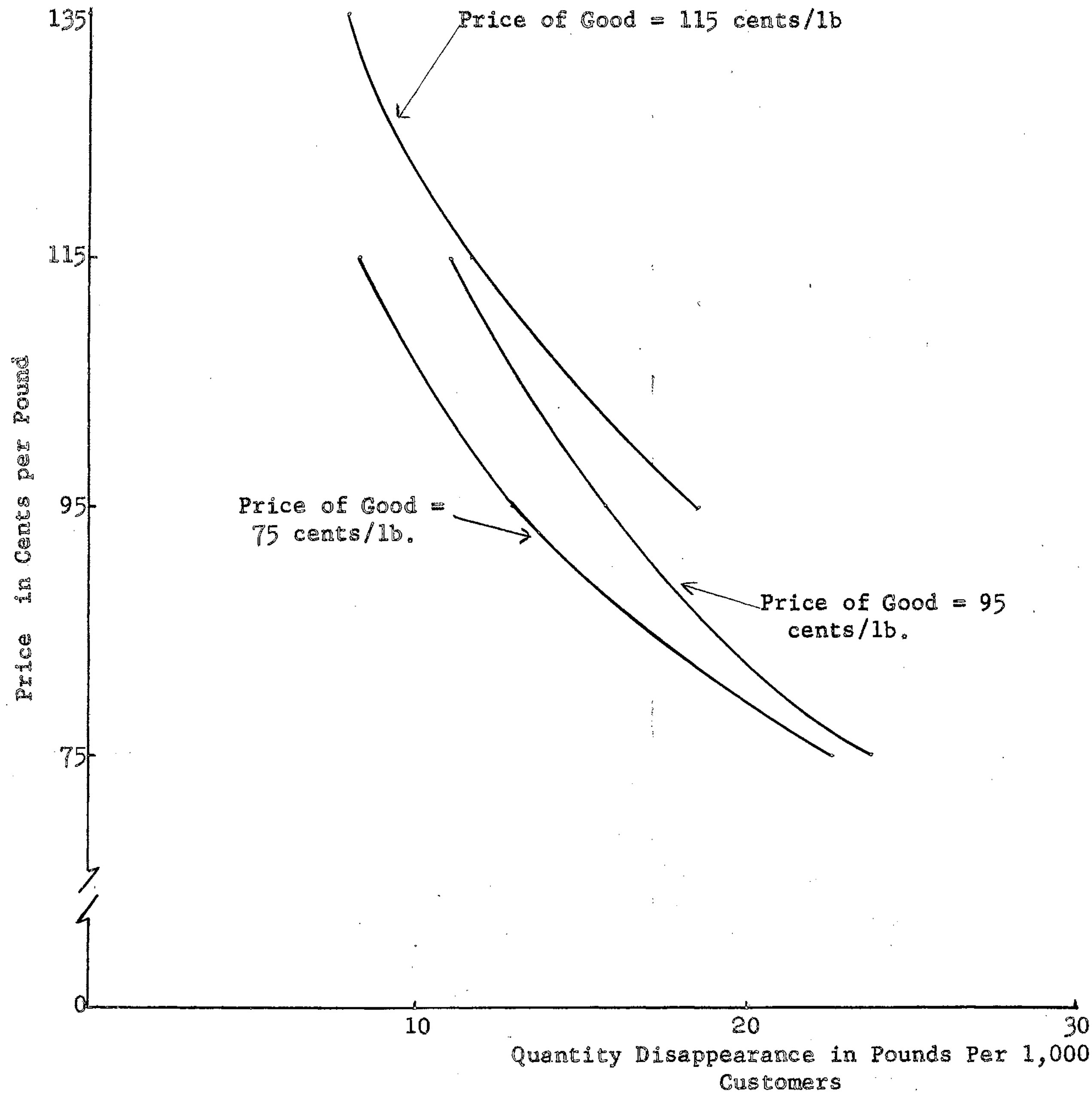

Figure 4.1 Price-Consumption Relationships for Choice Grade T-bone Steaks at Varying Prices for Good Grade T-bone Steaks

the logarithmic form to the original price and quantity units, illustrates the evidence concerning the influence of the price of Good grade steaks. As might logically be expected, the response curves for Choice grade steaks shifted to the right as the price level of Good grade steaks increased. This indicates that these two commodities are substitutes. However, the magnitude of these shifts may be insignificant.

If the magnitude of these shifts is assumed insignificant, the quantity disappearance of Choice grade steaks may be postulated as a function of the price of Choice steaks alone. The quantified result of such a function, linear in logarithms and based on all nine treatments, is presented in equation 4.9.

$$\hat{y}_c = 4.99 - \underset{(0.39)}{1.93}\, p_c \qquad r^2 = 0.78,\quad t = -4.95,\quad t_{.05} = 2.36 \tag{4.9}$$

where all variables have been defined in equation 4.6. This relationship also indicates that the price of Choice alone accounts for 78 percent of the variation in sales of Choice grade steak.

If the magnitude of the shifts due to a changing price level for Good grade steaks is not insignificant, then the quantity disappearance may be expressed as a function of the prices of the two grades of T-bone steak. Estimates of the parameters of such a function, linear in logarithms, are presented in equation 4.10.

$$\hat{y}_c = 4.10 - \underset{(0.37)}{2.19}\, p_c + \underset{(0.40)}{0.72}\, p_g \qquad r^2 = 0.86,\quad t_{pc} = -5.92,\quad t_{pg} = 1.80,\quad t_{.05} = 2.45 \tag{4.10}$$

where p_g represents the logarithm of the price of Good grade T-bone steaks in cents per pound and all other variables have been defined in equation 4.6. Equation 4.10 indicates a price elasticity of -2.19. Since the coefficient associated with p_g is not statistically significant, little can be said concerning the effects of price changes in p_g on the disappearance of Choice grade T-bone steak.

Since total expenditures on T-bone steaks fluctuated widely during the period studied, average value of meat sales was introduced as an additional variable in an attempt to explain these fluctuations. The quantity disappearance of Choice grade steaks was then postulated as a function of the price of Choice grade steak, the price of Good grade steak, and the average value of meat sales. Specifying a relationship linear in logarithms leads to the parameter estimates presented in equation 4.11.

$$\hat{y}_c = 4.19 - \underset{(0.45)}{2.19}\, p_c + \underset{(0.44)}{0.72}\, p_g - \underset{(1.63)}{0.03}\, i \qquad \begin{aligned} r^2 &= 0.86 \\ t_{pc} &= -4.86 \\ t_{pg} &= 1.64 \\ t_i &= -0.02 \\ t_{.05} &= 2.57 \end{aligned} \qquad (4.11)$$

where all variables have been defined in equations 4.5 and 4.6. This equation implies that the quantity of Choice T-bone steaks sold bears little relationship to the average value of meat sales.

Since no other cardinal measure of expenditures on T-bone steak independent of the experiment was available, an attempt to eliminate the effects of variation in expenditures was made by selecting those treatments where expenditures were relatively constant. The quantity disappearance of Choice grade T-bone steaks can be postulated as a function of the price of Choice grade steaks and the price of Good grade steaks when T-bone expenditures are constant. Treatments 1, 2, 5, 6, and 9 satisfy this condition. The quantitative result of such a relationship is presented in equation 4.12.

$$y_c = 0.45 - \underset{(0.28)}{0.86}\, p_c + \underset{(0.16)}{1.21}\, p_g \qquad \begin{array}{l} r^2 = 0.97 \\ t_{pc} = -3.07 \\ t_{pg} = 7.56 \\ t_{.05} = 4.30 \end{array} \qquad (4.12)$$

where all variables have been defined in equations 4.6 and 4.10.

These results indicate that Choice grade T-bone steaks exhibit an inelastic response to price over a range of 95-115 cents per pound. Equation 4.12 indicates the price of good grade steaks is an important determinant of Choice grade steak sales within this range. A graphical representation of this relationship expressed in terms of the original price and quantity units is presented in Figure 4.2.

3. Results for Good Grade T-bone Steaks

Prior to estimating the response relationships for Good grade T-bone steaks, adjustments for locational and time factors must be made as was the case for Choice T-bones and for the aggregate. Again, the analysis of variance technique was used.

a. The analysis of variance

The results of the analysis of variance for Good grade T-bone steaks are presented in Table 4.5. From the information in Table 4.5, it is evident that the pricing treatments and locational factors were the most important sources of variation in the sales of Good grade T-bone steaks. Results from the multiple range test indicate that sales of Good grade T-bone steaks decreased significantly as price increased from 95 to 115 cents per pound when Choice was priced at 115 cents per pound. When Choice grade T-bone steaks were priced at 95 cents per pound,

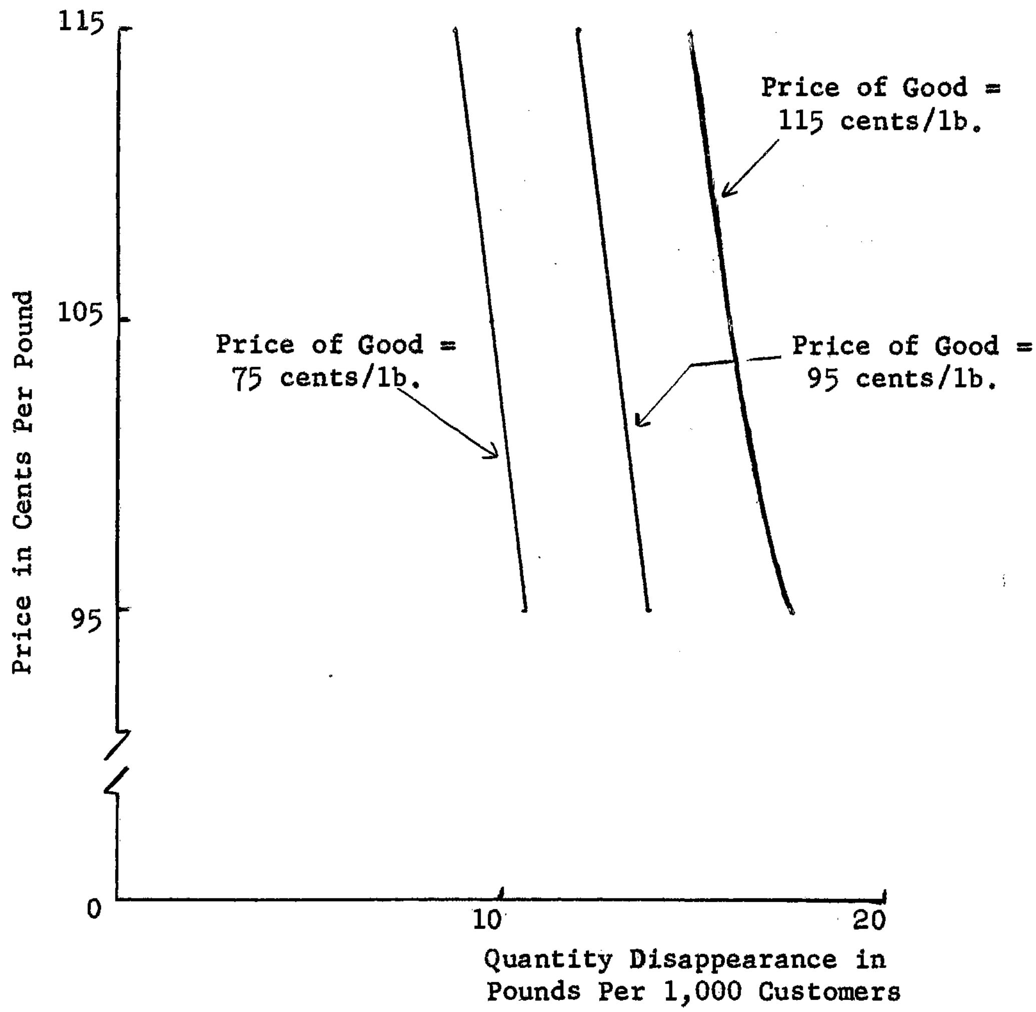

Figure 4.2 Price-Response Relationships for Choice Grade T-bone Steaks at a Fixed Expenditure Level

significant decreases in Good grade T-bone steak sales were detected when the price increased from 75 to 95 cents per pound, and when the price increased from 95 to 115 cents per pound.

TABLE 4.5

ANALYSIS OF VARIANCE FOR GOOD GRADE T-BONE STEAKS

Source of Variation	d.f.	Sum of Squares	Mean Square	F	$F_{.01}$
Total	67	8,074.557			
Stores	7	2,374.620	339.231		
Days	8	319.069	39.884		
Treatments (adjusted for days)	8	3,789.986	473.748	13.10	2.94
Error	44	1,590.882	36.156		

Standard Error of a Treatment Mean = 2.12

Treatment Means

t_7	t_4	t_1	t_2	t_5	t_8	t_9	t_6	t_3
3.35	9.32	10.06	12.32	14.13	14.98	19.48	24.36	28.16

b. Response relationships

As in the case of Choice grade steaks, the estimates of the parameters connecting price and sales of Good grade steaks are based on a simple model, linear in logarithms. A separate relationship is presented for each of the price levels of Choice grade steaks. Equation 4.13 represents the estimated relationship connecting price and sales of Good grade T-bone steaks over a range of 115-75 cents per pound when

Choice grade steaks were priced at 115 cents per pound (Treatments 1, 5, and 9). Equation 4.14 presents a similar relationship when Choice grade steaks were priced at 95 cents per pound (Treatments 2, 6, and 7).

$$y_g = 3.96 - \underset{(0.04)}{1.42}\, p_g \qquad r^2 = 0.999 \quad t = -35.50 \quad t_{.05} = 12.71 \tag{4.13}$$

$$y_g = 10.02 - \underset{(1.12)}{4.58}\, p_g \qquad r^2 = 0.94 \quad t = -4.09 \quad t_{.05} = 12.71 \tag{4.14}$$

where y_g represents the logarithm of the quantity disappearance of Good grade T-bone steaks in pounds per 1,000 customers and other variables have been defined in equation 4.10.

The relationship presented in equation 4.13 provides an estimate of price elasticity of -1.42. It should be pointed out in connection with this relationship that T-bone expenditures were approximately constant throughout the price range.

Equation 4.14 provides an estimate of price elasticity of -4.58 over the price range 115-75 cents per pound when Choice grade steaks were priced at 95 cents per pound. Since T-bone expenditures for treatment 7 were only about 1/8th the size of the expenditures in treatments 2 and 6, the magnitude of the resulting parameter is judged to be overestimated. This fact is particularly evident in a graphical representation of the two equations (Figure 4.3) converted from the logarithmic form to the original price and quantity units.

The influence of the value of meat sales on this grade of T-bone was investigated by postulating a relationship where the quantity disappearance of Good grade steak was a function of the price of Good grade steak,

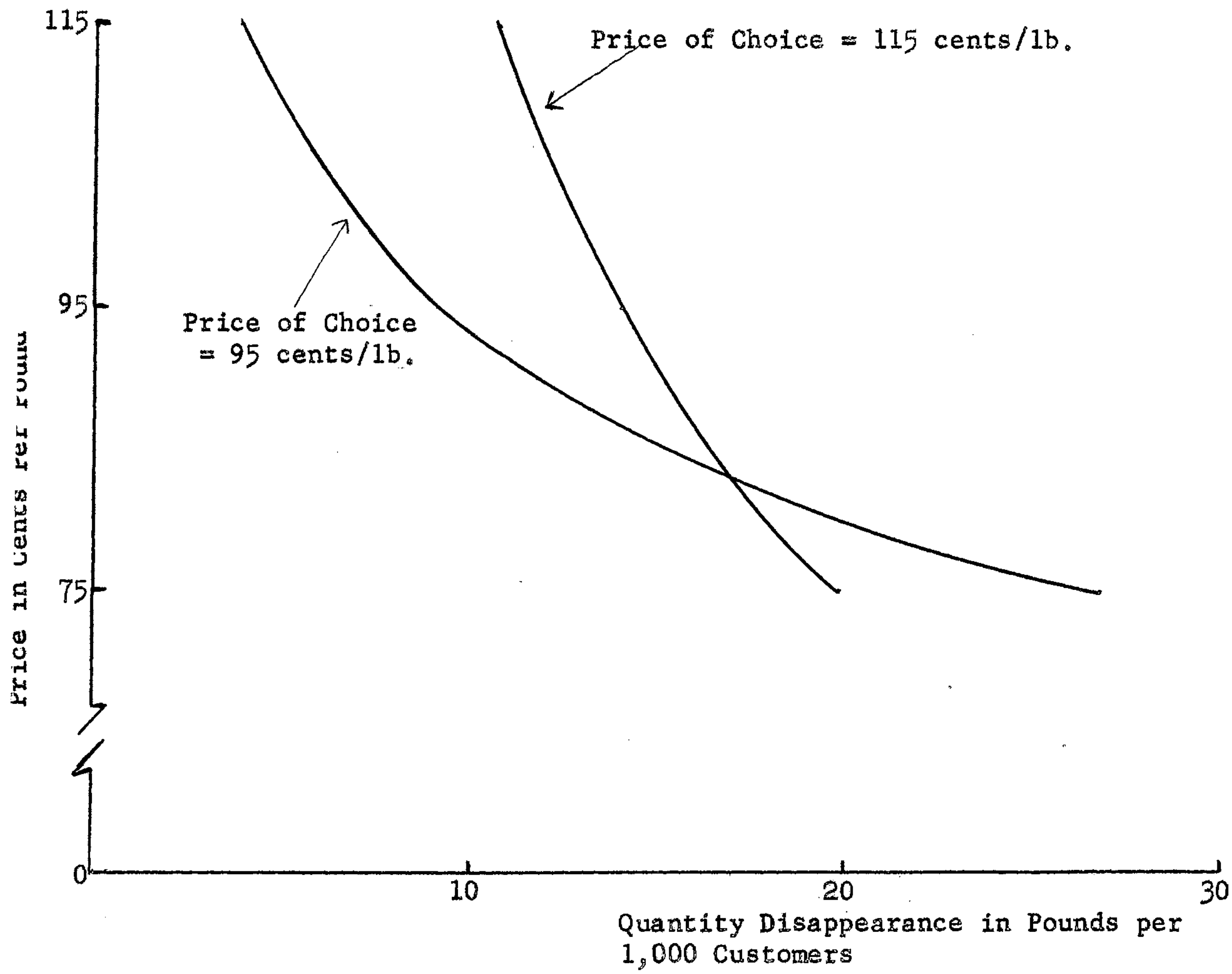

Figure 4.3 Price-Consumption Relationships for Good Grade T-bone Steaks at Varying Prices for Choice Grade T-bone Steaks

the price of Choice grade steak, and the average value of meat sales. Quantifying such a model resulted in the estimates presented in equation 4.15.

$$\hat{y}_g = -2.33 - \underset{(0.81)}{3.00}\, p_g - \underset{(0.82)}{0.09}\, p_c + \underset{(3.00)}{3.02}\, i \qquad \begin{array}{l} r^2 = 0.76 \\ t_{pg} = -3.70 \\ t_{pc} = -0.11 \\ t_i = 1.01 \\ t_{.05} = 2.57 \end{array} \qquad (4.15)$$

where all variables have been defined in equations 4.5, 4.10 and 4.13.

As in the case of Choice grade steaks, no well defined relationship between sales of Good grade steaks and average value of meat sales is apparent. This relationship also implies that the price of Choice grade T-bone has little effect on the sales of good grade T-bone steak.

By employing only those treatments where steak expenditures were constant, more valid estimates of the parameters connecting the price of these two grades of steak to the quantity of Good grade steak may be obtained. Expressing these variables in a linear logarithmic form resulted in the quantitative estimate presented in equation 4.16.

$$\hat{y}_g = 4.75 - \underset{(0.76)}{0.06}\, p_c - \underset{(0.44)}{1.76}\, p_g \qquad \begin{array}{l} r^2 = 0.90 \\ t_{pc} = -0.08, \\ t_{pg} = -4.00 \\ t_{.05} = 4.30 \end{array} \qquad (4.16)$$

where all variables have been defined in equations 4.10 and 4.13. From this relationship the price elasticity of Good grade T-bone steaks is estimated as -1.76. In this relationship, as in equation 4.15, the price of the competing grade appears to have little influence on the sales of Good grade T-bone steak. On the basis of these results, Good grade steaks are elastic over the range of prices from 75-115 cents per pound. The results of equation 4.16 are presented graphically in Figure 4.4.

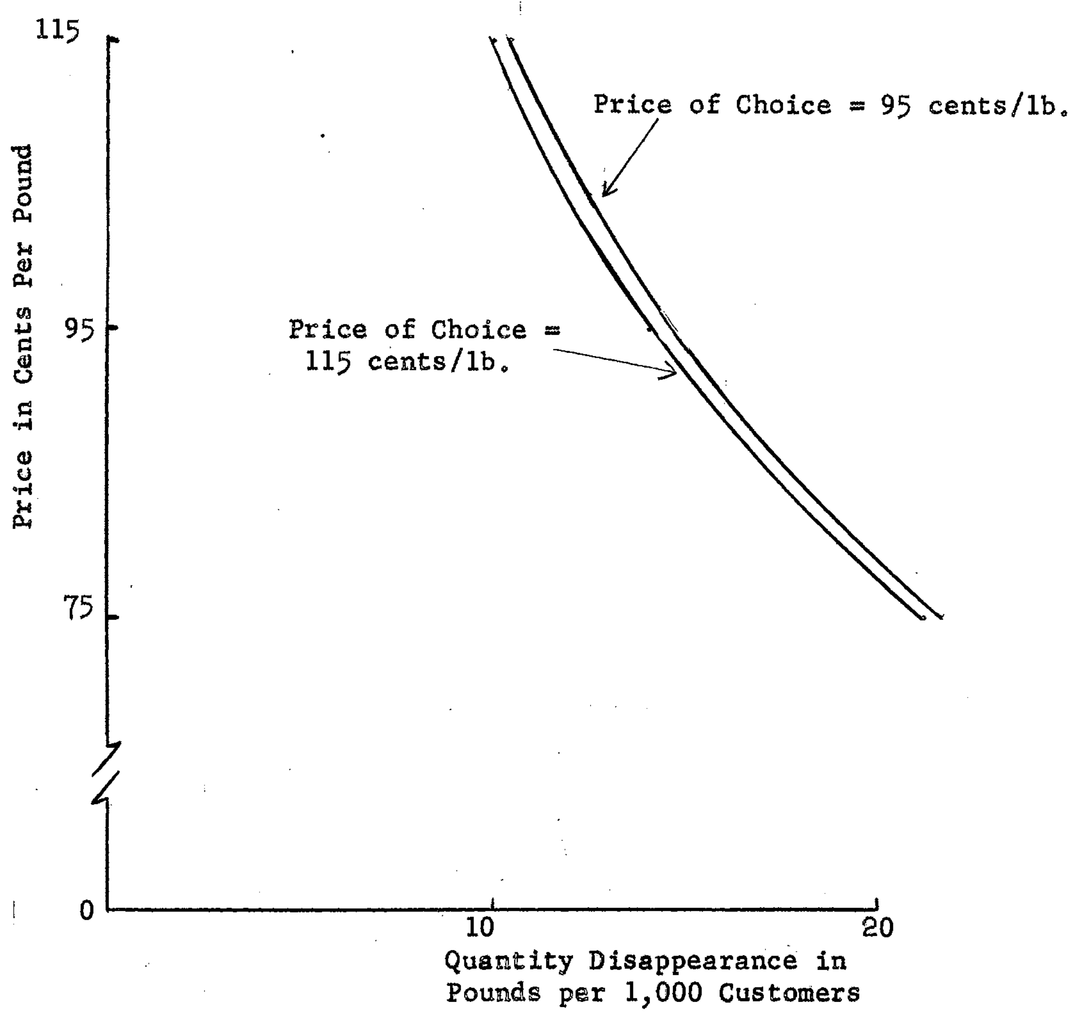

Figure 4.4 Price-Response Relationships for Good Grade T-bone Steaks at a Fixed Expenditure Level

4. Effects of Price Level Changes on the Consumption of T-bone Steaks

Considerable interest has risen among some economists with respect to the question of consumer preferences among alternative grades of meat.[25] A common technique employed to answer this question has been to record the responses of consumers to a given set of alternatives when the alternatives are priced alike at some one level. Data generated by Treatments 1, 2, and 3 were employed in order to ascertain the impact of the level of price on the structure of consumption. The results presented in Table 4.6 indicate that extreme caution should be exercised in evaluating consumer preferences based on a single price level.

TABLE 4.6

STRUCTURE OF STEAK SALES UNDER ALTERNATIVE LEVELS OF PRICES AS PERCENTAGE OF CHOICE OR GOOD GRADES

Treatment	Price/lb.	Choice	Good	Total
1	115	60.143	39.857	100.00
2	95	54.542	45.458	100.00
3	75	47.253	52.747	100.00

[25] R. E. Branson, The Consumer Market for Beef, Texas Agricultural Experiment Station Bulletin 856, April, 1957.

V. J. Rhodes, E. R. Kiehl and D. E. Brady, Visual Preferences for Grades of Retail Beef Cuts, Missouri Agricultural Experiment Station Bulletin 583, June, 1955.

R. E. Seltzer, Consumer Preferences for Beef, Arizona Agricultural Experiment Station Bulletin 267, October, 1955.

The sample data presented in Table 4.6 provided evidence that at a relatively high price per pound, consumers tended to buy the Choice grade. At a relatively low price level, consumers tended to buy the Good grade. At close to the "normal" market price, the percentage disappearance of the two grades tended to be equal.

Alternatively, the data of Table 4.6 can be presented in a graphical form which compares the price-consumption relationships between the two grades and the aggregate. These relationships are presented in Figure 4.5 and have been converted from the logarithmic form to relationshipsin the original units. These relationships demonstrate perhaps more clearily that, even within a given market, a wide degree of expressed preferences between two grades of steak may be obtained depending on the price level chosen for sampling the preferences.

a. Response relationship for aggregate of T-bone steaks

In addition to the above considerations, changing cost structures may suggest to retailers the need of a uniform price change for meat items. Information concerning the change in consumption following such a price change would, of course, be desirable. Information of this type relative to T-bone steaks is presented in equation 4.17. The data for this relation were generated by Treatments 1, 2, and 3.

$$\hat{y} = 5.06 - \underset{(0.70)}{1.80}\, p \qquad r^2 = 0.87,\quad t = -2.57,\quad t_{.05} = 12.71 \tag{4.17}$$

where all variables have been defined in equation 4.4. This relationship was generated from treatments where both grades of T-bone steak were priced alike and subjected to the same price differential between treatments. As in the two previous equations, the price coefficient yields an

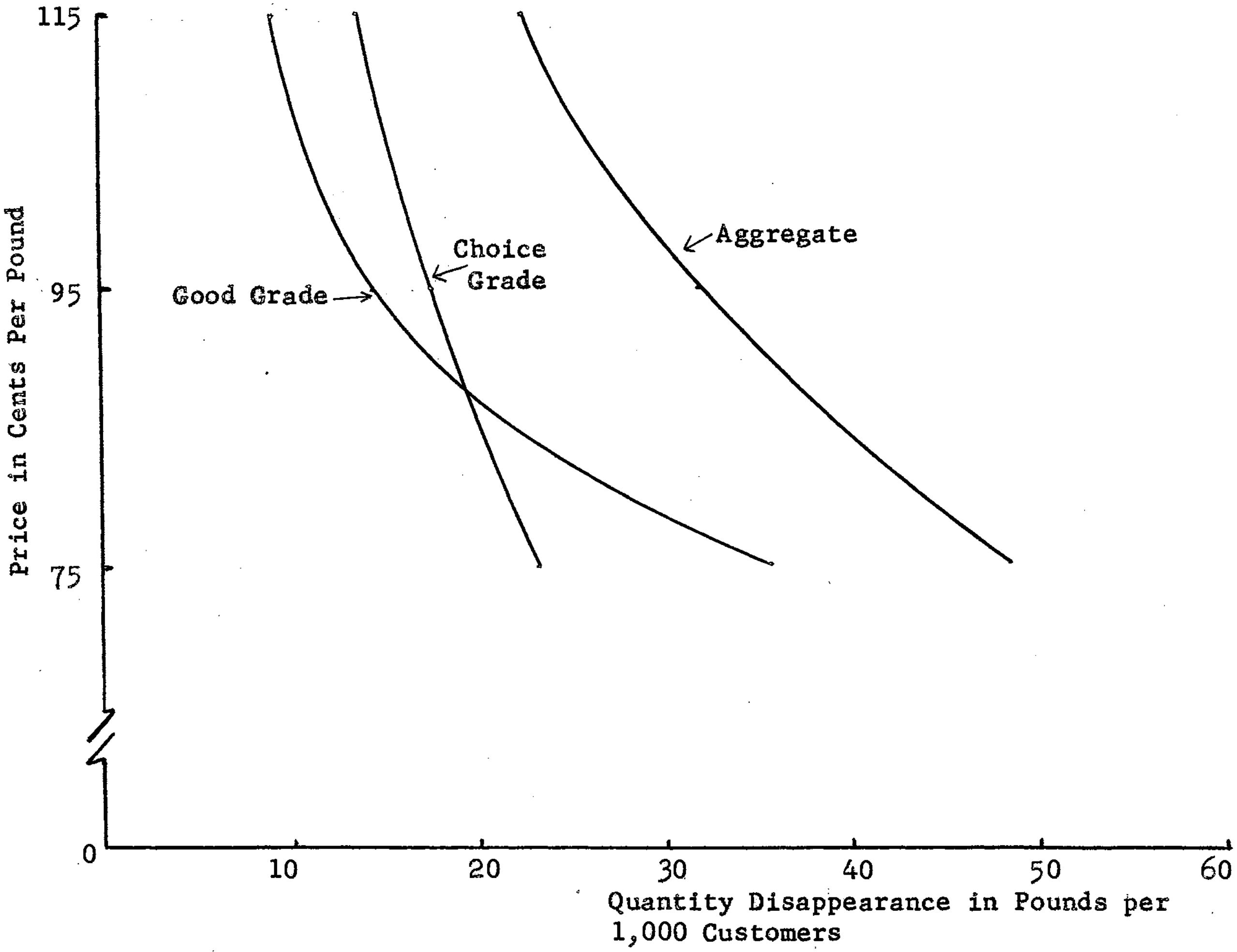

Figure 4.5 Price-Consumption Relationships for T-bone Steaks by Grades and for the Aggregate Under Three Price Level Treatments

estimate of the retail price elasticity. For comparative purposes, an equation was estimated which excluded Treatment 4.[26] The results are presented in equation 4.18.

$$\hat{y} = 5.44 - \underset{(0.39)}{2.00}\, p \qquad \begin{array}{l} r^2 = 0.81 \\ t = -5.13 \\ t_{.05} = 2.45 \end{array} \qquad (4.18)$$

where all variables have been defined in equation 4.4. It is apparent from equations 4.17 and 4.18 that the estimate of elasticity under price level changes is not appreciably different from the estimate of elasticity under the alternative pricing scheme.

b. Response relationship for Choice grade T-bone steaks

Under the type of economic change discussed above, the relative prices of two or more goods may remain constant while the absolute level of prices changes. Since the nature of the response by grades to price changes of this type may differ considerably from the response to alternative pricing schemes, it would be desirable to have an estimate of the response relationship resulting from such conditions. Treatments 1, 2, and 3 provided an independent source of data for computing such a relationship. Equation 4.19 represents an estimate of the response of Choice grade steak to price when both grades of steak were subjected to equal and simultaneous price changes.

$$\hat{y}_c = 3.67 - \underset{(0.68)}{1.23}\, p_c \qquad \begin{array}{l} r^2 = 0.76 \\ t = -1.81 \\ t_{.05} = 12.71 \end{array} \qquad (4.19)$$

where all variables have been defined in equation 4.6.

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[26] Inclusion of Treatment 4 would result in a comparison over unequal price ranges.

This relationship does not have the same economic meaning as the previous relationships since the price of the competing grade was not held constant. In addition, this equation suffers somewhat to the extent of the shift in T-bone expenditures.

c. Response relationship for Good grade T-bone steaks

Treatments 1, 2 and 3 may be used to obtain a relationship between the quantity disappearance of Good grade steaks and the price of Good grade steak under conditions of a changing level of prices. Quantifying this simple model, linear in logarithms, results in the parameter estimate presented in equation 4.20.

$$y_g = 6.01 - \underset{(0.69)}{2.45}\, p_g \qquad r^2 = 0.93 \quad t = 3.55 \quad t_{.05} = 12.71 \tag{4.20}$$

where all variables have been defined in equations 4.10 and 4.13.

This relationship indicates that the response of Good grade steak to price is relatively elastic. No direct comparison can be made with the previous estimates of elasticity since this relationship contains a bias due to shifts in T-bone expenditures. A comparison with the estimate of elasticity of Choice grade steaks under the same pricing conditions reveals that consumers of Good grade steaks are considerably more responsive to price than consumers of Choice grade steaks.

V. ANALYSIS FOR FRESH FRYERS

Although it would be desirable to base an evaluation of the experimental method of generating economic data on an analysis of more than three food products, fresh fryers was selected as the final product for investigation.

The feasibility of generating data useful in estimating price-response relationships for fresh fryers was investigated by following the procedures employed with the two previous products. These procedures involve the following steps: (1) the specification of the economic models, (2) the classification of variables according to the criteria set forth in Chapter II, (3) the transition to a statistical model, and (4) the selection of an appropriate design of experiment.

A. The Economic Models

1. Individual Types of Fryers[27]

The quantity of fresh fryers purchased can be expected on theoretical grounds to be influenced by the price of fresh fryers, the prices of related goods, and the level and distribution of consumer incomes.

The price variables may be considered to be of particular importance in the short-run because of their effect on consumers' budget restraint and on the producer's total revenue. A model relating quantities purchased

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[27]For the purposes of this study fresh fryers were classified into two types: whole and cut-up.

to prices may be postulated as:

$$y_i = f(p_i, p_j, z_1, z_2, \ldots, z_n; \alpha_1, \alpha_2, \ldots, \alpha_{n+3}) \qquad (5.1)$$

where y_i represents the quantity disappearance of a particular type of fryer, p_i represents the retail price of that particular type of fryer, p_j represents the retail price of a competing type of fresh fryer, z_1, z_2, ..., z_n represent vectors of other preference variables, and α_1, α_2, ..., α_{n+3} represent a set of parameters to be estimated.

Model 5.1 was used to investigate the effects of two types of price changes. The first of these concerned the response of consumers to a price change in a particular type of fresh fryer when all other factors are fixed at a predetermined level. The second concerned the relative shifts in consumption of the two types of fryers stimulated by a uniform price level change in these products.

2. Aggregate of Types

For certain economic decisions interest centers on the total consumption of fryers rather than on that of an individual type. A model, analagous to 5.1, was specified which postulates a relationship between the quantity disappearance of all types of fresh fryers and the average retail price of fryers. Such a model is presented in equation 5.2.

$$y = f(p, z_1, z_2, \ldots, z_n; \alpha_1, \alpha_2, \ldots, \alpha_{n+2}) \qquad (5.2)$$

where y represents the quantity disappearance of both types of fresh fryers, p represents the average retail price of the two types of fresh fryers, z_1, z_2, ..., z_n represent vectors of other variables influencing the consumption of fresh fryers, and α_1, α_2, ..., α_{n+2} are parameters to be estimated.

An alternative model can be specified which makes explicit the influence of the price of each type of fryer on the total disappearance of fresh fryers. This formulation is presented in equation 5.3.

$$y = f(p_i, p_j, z_1, z_2, \ldots, z_n; \alpha_1, \alpha_2, \ldots, \alpha_{n+3}) \qquad (5.3)$$

where all variables have been defined in equations 5.1 and 5.2.

B. The Setting

The study was conducted in greater Oklahoma City, Oklahoma with the cooperation of five large, modern, self-service markets operating under the management of Humpty-Dumpty Stores. The stores were selected such that shifts in place of purchase from one test store to another was not likely to occur. Shifts from the test to neighborhood stores under slightly higher than average pricing conditions were assumed to be negligible. The selection was also based on the heterogeneity of consumer groups among these stores.

The study was initiated on January 20, 1958 and terminated on January 30, 1958. The choice of such a time period permitted the treatment effects to occur in a relatively realistic short-run period. Furthermore, compressing the treatments into such a short time period permitted at least the direct effects of advertising to be eliminated from the data.

The test display consisted of Grade A whole fresh fryers and Grade A fryers cut up and packaged as a unit. Biases arising due to position in the display were minimized by rotating the two types daily according to a prearranged random schedule. The position of the fryers relative to other cuts of meat and the size of the fryer display were maintained in accord with the normal store procedure.

Pricing of the fryers was varied according to the schedule presented in Table 5.1. The treatments were randomized according to the design presented in Table 5.2.

TABLE 5.1

PRICING TREATMENTS FOR OKLAHOMA CITY RETAIL FRYER EXPERIMENT

	Treatments (cents per pound)										
Type	1	2	3	4	5	6	7	8	9	10	11
Whole	41	43	45	47	49	41	41	45	45	49	49
Cut-up	47	49	51	53	55	51	55	47	55	51	47

TABLE 5.2

RANDOMIZATION OF PRICING TREATMENTS FOR OKLAHOMA CITY FRESH FRYER EXPERIMENT, JANUARY, 1958

	Store Code Number				
Day	1	2	3	4	5
January 20	t_9	t_8	t_4	t_{10}	t_3
January 21	t_4	t_5	t_2	t_3	t_1
January 22	t_{11}	t_{10}	t_6	t_4	t_2
January 23	t_{10}	t_3	t_1	t_6	t_7
January 24	t_1	t_4	t_9	t_7	t_{11}
January 25	t_5	t_9	t_3	t_{11}	t_6
January 26	t_8	t_1	t_{11}	t_5	t_{10}
January 27	t_3	t_{11}	t_7	t_2	t_8
January 28	t_2	t_7	t_{10}	t_9	t_5
January 29	t_6	t_2	t_8	t_1	t_9
January 30	t_7	t_6	t_5	t_8	t_4

Treatments 1 through 5 were designed to provide information on the effects of uniform price level changes on the total consumption of fryers and the relative consumption of the two types.

Three sets of treatments were designed to provide information on the response of consumers to price changes in whole fryers. Treatments 1, 8, and 11 were designed to provide information on this relationship when the price of cut-up fryers was maintained at 47 cents per pound. Treatments 3, 6, and 10 were designed to provide data for a similar relationship when cut-up fryers were priced at 51 cents per pound. Treatments 5, 7, and 9 were designed to provide information on any price response when cut-up fryers were priced at 55 cents per pound.

Three sets of pricing treatments also were designed to elicit price response information for cut-up fryers at varying price levels for whole fryers. Treatments, 1, 6, and 7 were intended to provide data for the estimation of the response relationships for cut-up fryers when whole fryers were priced at 41 cents per pound. Treatments 3, 8, and 9 were designed to perform a similar function when whole fryers were priced at 45 cents per pound; and treatments 5, 10, and 11 were designed to provide such data when whole fryers were priced at 49 cents per pound.

Such a pricing structure limited the price spread within each type of fryer to eight cents per pound and the price spread between types to a maximum of fourteen cents per pound.

C. The Statistical Model and the Design of Experiment

1. Transition to the Statistical Model

The transition from the economic models for fresh fryers to the statistical models is based on logic similar to that employed in the eggs and steaks experiments. The variable classification applied in the two previous analyses is introduced at this point and some set of variables, say z_m, ..., z_n are designated as uncontrolled and unobserved variables and assumed to act collectively in a random manner. The price variables, p_i, and p_j are designated as variables that are controlled over some range. The variables z_1, z_2, ..., z_m are considered as fixed at a particular level.

The foregoing considerations relative to the specification of the economic models, classification of variables and the restriction on the number of days during which the study could be conducted as well as the restriction on the number of stores available for sampling, led to the following statistical model:

$$y_{ijk} = m + s_i + d_{ik} + p_k + \beta(z_{ijk} - \bar{z}) + e_{ijk} \qquad (5.4)$$

where y_{ijk} represents the quantity disappearance of fresh fryers, m represents the overall mean effect, s_i represents the store effects, d_{ik} represents the incomplete block, or day, effect, p_k represents the price effect, $z_{ijk} - \bar{z}$ is a covariant representing level of income, β represents the covariance parameter and e_{ijk} is the intra-block residual or error, assumed to be normally and independently distributed with mean zero and variance σ^2.

D. The Results

1. Results for Aggregate Fresh Fryers

a. Analysis of variance

The analysis for fresh fryers was conducted in a manner similar to that for T-bone steaks. The data were subjected first to an analysis of variance and then to an analysis relating the adjusted quantity disappearance to the pricing treatments. The analysis of variance appears in Table 5.3.

TABLE 5.3

ANALYSIS OF VARIANCE[28]

Source	d.f.	Sum of Squares	Mean Square	F	F_{05}
Treatments (adj. for days)	10	10.9093	1.0909	0.646	2.19
Error	28	47.2652	1.6880		
Treatment + Error	38	58.1745			

The results of Table 5.3 indicate that the pricing treatments employed did not significantly affect the quantity disappearance of the two types of fresh fryers studied, which suggests an inelastic response to price.

b. Response relationships for aggregate of fryers

Although the above results indicate a non-significant response to price there may be some value in the magnitude of the connecting parameter. An estimate of the parameter connecting the quantity disappearance of both types of fryers with their average price is presented in equation 5.5.

$$\hat{y}_a = 9.6115 - \underset{(0.5183)}{0.0476}\, p \qquad r^2 = 0.05,\; t = -0.09,\; t_{.05} = 2.26 \qquad (5.5)$$

[28]The complete analysis of variance is reported in Appendix Table B.1.

where $\hat{y}_a$ represents the quantity disappearance of the aggregate of fryer types in fryers per 1,000 customers and p represents the average retail price of the two fryer types in cents per pound. The two statistical tests appearing with the relation reiterate the results of Table 5.3.

Since retailers may have an interest in the relative effect of price changes in a particular type of fryer on total fryer sales, the aggregate relation was re-estimated using the prices of the individual fryer types. The result is presented in equation 5.6.

$$\hat{y}_a = 9.4698 - \underset{(0.0528)}{0.0474}\, p_w - \underset{(0.0528)}{0.0002}\, p_c \qquad \begin{array}{l} R^2 = 0.09 \\ t_{pw} = -0.89 \\ t_{pc} = -0.00 \\ t_{.05} = 2.31 \end{array} \qquad (5.6)$$

where p_w represents the retail price of whole fresh fryers in cents per pound, p_c represents the retail price of cut-up fresh fryers in cents per pound and all other variables have been defined in equation 5.5.

The estimates of the parameters obtained for the above relation, although not statistically different from zero, suggest that the price of whole fresh fryers may exert more influence on the total quantity disappearance of fryers than does the price of the other type.

2. The Results for Cut-up Fresh Fryers

a. Analysis of variance

An analysis of variance was performed to investigate the store and day effects on cut-up fryer sales. The results of this analysis are presented in Table 5.4.

In contrast with the analysis for all fryers the analysis for cut-up fryers embodies an F statistic which is significant at the five percent probability level. A further investigation of the effects of price changes is contained in the response relationships presented below.

TABLE 5.4

ANALYSIS OF VARIANCE FOR CUT-UP FRYERS[29]

Source	d.f.	Sum of Squares	Mean Square	F	F_{05}	F_{01}
Treatments (adj. for days)	10	28.9367	2.8937	2.21	2.19	3.03
Error	28	36.6741	1.3098			
Treatments + Error	38	65.6108				

b. Response relationships for cut-up fresh fryers

Simple linear models were used to relate cut-up fresh fryer sales to price. A separate relationship was estimated for each of the price levels of whole fresh fryers. Equation 5.7 presents the estimated relationship connecting price and sales of cut-up fresh fryers over a range of 47 cents per pound to 55 cents per pound when whole fresh fryers were priced at 41 cents per pound (Treatments 1, 6, and 7). Equation 5.8 presents a similar relationship when whole fryers were priced at 45 cents per pound (Treatments 3, 8, and 9) and equation 5.9 presents a relationship when whole fryers were priced at 49 cents per pound (Treatments 5, 10, and 11).

$$\hat{y}_c = 6.8279 - \underset{(0.0663)}{0.0583}\, p_c \qquad r^2 = 0.44,\quad t = -0.88,\quad t_{.05} = 12.71 \qquad (5.7)$$

[29]See Appendix Table B.2 for the complete analysis.

$$\hat{y}_c = 6.1112 - \underset{(0.03958)}{0.0338}\, p_c \qquad r^2 = 0.42,\ t = -0.85,\ t_{.05} = 12.71 \tag{5.8}$$

$$\hat{y}_c = 21.6495 - \underset{(0.0612)}{0.3287}\, p_c \qquad r^2 = 0.97,\ t = -5.37,\ t_{.05} = 12.71 \tag{5.9}$$

where $\hat{y}_c$ represents the quantity disappearance of cut-up fresh fryers in fryers per 1,000 customers and all other variables have been defined in equation 5.6.

These relationships are presented in graphical form in Figure 5.1. The graphical form displays in a more obvious manner a certain degree of shift in the curves as the price of whole fryers increased. Inasmuch as the direction of the shift was to the right, it would appear that the two forms of fryers are to some degree substitutes. The elasticities associated with the three relationships are -0.77, -0.39, and -3.43 respectively.

To obtain an estimate of the substitutability between the two types of fryers a linear relationship expressing the quantity of cut-up fryers as a function of the price of cut-up fryers and the price of whole fryers was quantified. All eleven treatments were employed in the estimation of this relation which is presented in equation 5.10.

$$\hat{y}_c = 3.9864 - \underset{(0.0609)}{0.1209}\, p_c + \underset{(0.0609)}{0.1480}\, p_w \qquad R^2 = 0.53,\ t_{pc} = -1.98,\ t_{pw} = 2.43,\ t_{.05} = 2.31 \tag{5.10}$$

where all variables have been defined in equations 5.6 and 5.7.

The signs of the coefficients in this relationship signify that cut-up fryers constitutes a good which competes with whole fryers. The price elasticity was estimated at -1.38 and the cross elasticity was estimated at +1.49.

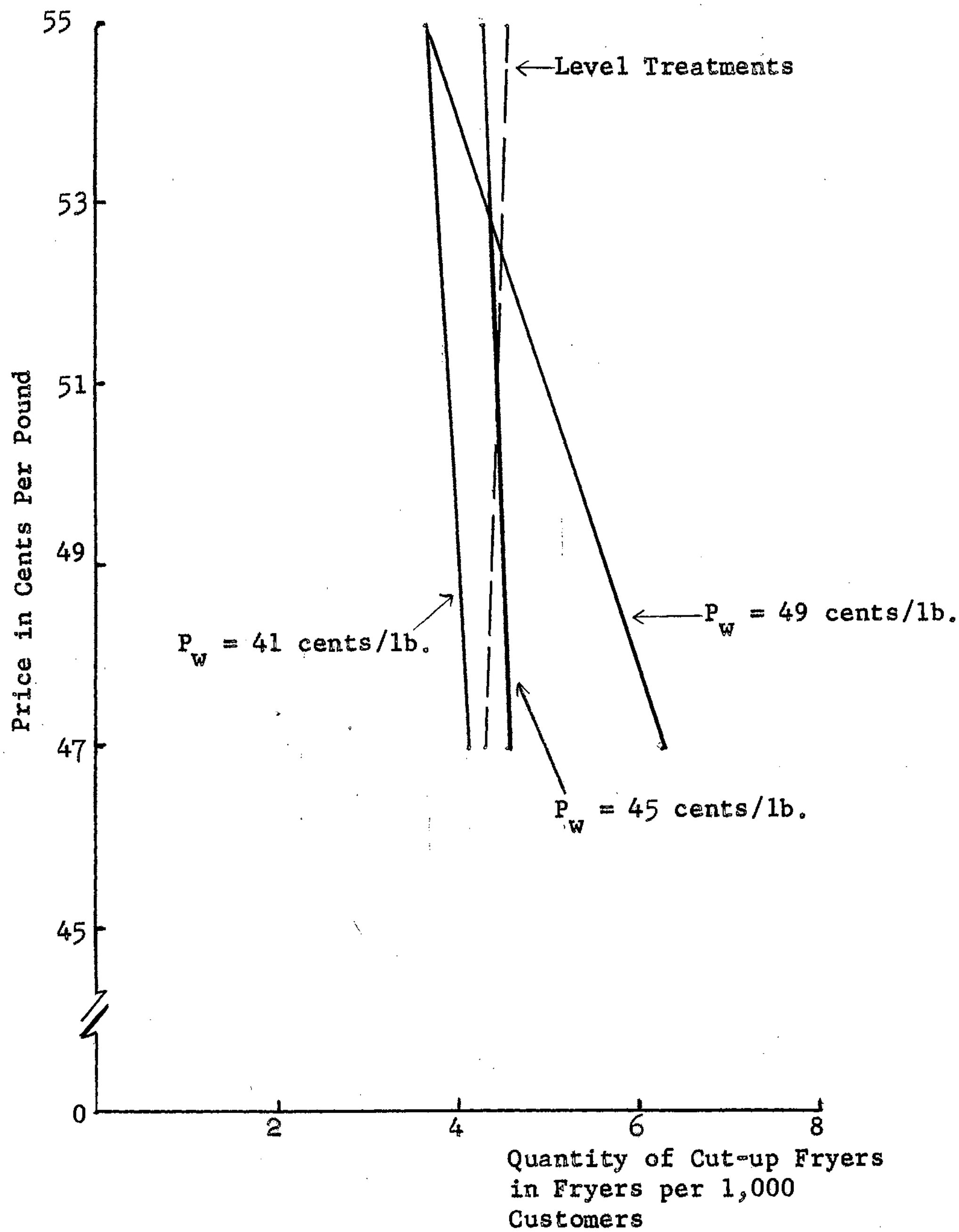

Figure 5.1 Price-Consumption Relationships for Cut-up Fresh Fryers

One additional response relationship was estimated for cut-up fresh fryers. This relationship was estimated in an attempt to ascertain the effect of price level changes on the sales of cut-up fryers. The data from treatments 1 through 5 were used for this purpose and the result is presented in equation 5.11.

$$\hat{y}_c = 2.9193 + \underset{(0.1233)}{0.0295}\, p_c \qquad r^2 = 0.02,\quad t = 0.24,\quad t_{.05} = 3.18 \tag{5.11}$$

where all variables have been defined in equations 5.6 and 5.7.

The parameter estimate for this relationship is not in conflict with the previous estimates and yields a "price elasticity" estimate of 0.34.

3. The Results for Whole Fresh Fryers

a. Analysis of variance

The analysis for whole fresh fryers exactly parallels that for cut-up fresh fryers. The results of the analysis of variance is presented in Table 5.5 and the complete analysis appears in Appendix Table B.3.

TABLE 5.5

ANALYSIS OF VARIANCE FOR WHOLE FRYERS

Source	d.f.	Sum of Squares	Mean Square	F	F_{05}	F_{01}
Treatments	10	23.9308	2.3931	2.34	2.19	3.03
Error	28	28.5803	1.0207			
Treatments + Error	38	52.5111				

The results presented in Table 5.5 indicate that the response in sales of whole fresh fryers to price changes over the range of 41 cents per pound to 49 cents per pound was significant at the 5 percent level of probability.

b. Response relationships for whole fresh fryers

Simple linear relationships were used to relate price to sales of whole fresh fryers. Separate relationships were estimated for each of the price levels for cut-up fresh fryers. Equation 5.12 presents the estimated relationship connecting price and sales of whole fryers over a range of 41 cents per pound to 49 cents per pound when cut-up fryers were priced at 47 cents per pound (Treatments 1, 8, and 11). Equation 5.13 presents a similar relationship when cut-up fryers were priced at 51 cents per pound (Treatments 3, 6, and 10) and equation 5.14 presents a relationship when cut-up fryers were priced at 55 cents per pound (Treatments 5, 7, and 9).

$$\hat{y}_w = \underset{}{14.4260} - \underset{(0.0165)}{0.2680}\, p_w \qquad r^2 = 0.99,\quad t = -16.24,\quad t_{.05} = 12.71 \tag{5.12}$$

$$\hat{y}_w = 9.5829 - \underset{(0.0226)}{0.1475}\, p_w \qquad r^2 = 0.97,\quad t = -6.53,\quad t_{.05} = 12.71 \tag{5.13}$$

$$\hat{y}_w = 11.4844 - \underset{(0.0017)}{0.1818}\, p_w \qquad r^2 = 0.99,\quad t = -106.94,\quad t_{.05} = 12.71 \tag{5.14}$$

where y_w represents the quantity disappearance of whole fresh fryers in fryers per 1,000 customers and all other variables have been defined previously.

Except for equation 5.13, the sign of the coefficient accompanying price agrees with the logic that as the price of a superior good rises consumption declines. For equations 5.12 and 5.14 the linear form described the relationship adequately over the range of prices studied. Elasticities based on the above three relationships were estimated at -5.10, -2.25, and -2.48 respectively. These relationships are presented in graphical form in Figure 5.2.

These relationships display further evidence of a competitive relationship with cut-up fryers in that the response curves shift to the right as the price of cut-up fryers is increased.

The degree of substitutability between these two types of fryers was estimated by quantifying a linear relationship which expresses the quantity of whole fryers as a function of the price of whole fryers and the price of cut-up fryers. All eleven treatments were employed in the estimation of this relationship which is presented in Equation 5.15.

$$\hat{y}_w = 5.5256 - \underset{(0.0204)}{0.1959}\, p_w + \underset{(0.0204)}{0.1204}\, p_c \qquad \begin{array}{l} R^2 = 0.94 \\ t_{pw} = -9.60 \\ t_{pc} = 5.90 \\ t_{.05} = 2.31 \end{array} \tag{5.15}$$

where all variables have been defined in equations 5.6 and 5.12. The sign of the coefficient connecting price and quantity of whole fryers conforms to the theoretical expectation. Estimates of the elasticity and cross elasticity based on the foregoing linear relation are -3.10 and +2.16 respectively.

The final relationship quantified for whole fryers was an attempt to relate the quantity of whole fryers to the price of whole fryers when the two fryer types were subjected to equal incremental price increases.

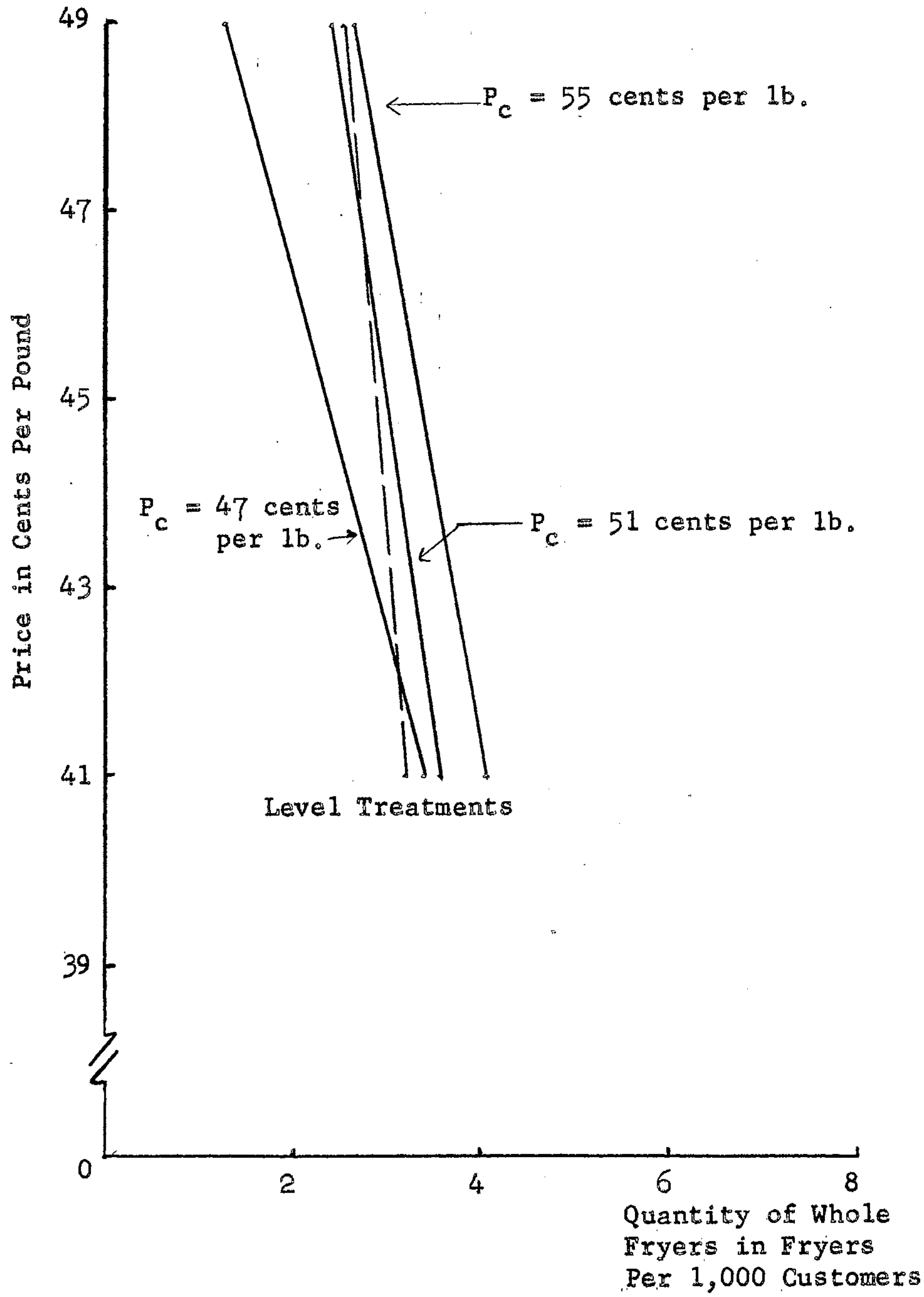

Figure 5.2 Price-Consumption Relationships for Whole Fresh Fryers

Treatments 1 through 5 were used for this purpose and the result is presented in equation 5.16.

$$\hat{y}_w = 7.2299 - \underset{(0.0401)}{0.0969}\, p_w \qquad r^2 = 0.75 \quad t = -2.42 \quad t_{.05} = 3.18 \qquad (5.16)$$

where all variables have been defined in equation 5.12.

Under this type of price change the quantity of whole fryers purchased did not change significantly over the price range of 41-49 cents per pound. This relationship yields a "price elasticity" estimate of -1.52. These results are not in conflict with the results obtained for the aggregate of fryer types.

The change in the relative consumption of these two types of fryers when subjected to price level changes is presented in percentage form in Table 5.6.

TABLE 5.6

RELATIVE PERCENTAGE CHANGES IN FRYER CONSUMPTION UNDER PRICE LEVEL CHANGES

Treatment	1	2	3	4	5
Cut-up	53.115	61.296	61.698	67.339	59.014
Whole	46.885	38.704	38.302	32.661	40.986
Total	100.000	100.000	100.000	100.000	100.000

VI. SUMMARY AND CONCLUSIONS

This research was undertaken to investigate the effectiveness of controlled experiments in generating data describing consumers' response to price. Three controlled experiments were conducted, each providing data for the estimation of price response relationships for a separate commodity. The first experiment, conducted in eleven retail food stores in Tulsa, Oklahoma, provided data for the estimation of price-response relationships for graded eggs. A total of nine one-day pricing treatments in a randomized blocks design were applied on Friday and Saturday of each week from July 6 to August 3, 1956. The second experiment, conducted in eight retail food stores in Tulsa, Oklahoma, provided data for the estimation of price response relationships for T-bone steaks cut from graded beef. A total of nine one-day pricing treatments in a Youden square design were applied on Thursday, Friday and Saturday for three weekends beginning February 7, 1957. The third experiment, conducted in five retail food stores in Oklahoma City, Oklahoma provided data for the estimation of price response relationships for two types of fresh fryers. A total of eleven one-day pricing treatments in a youden square design were applied for eleven consecutive days in January, 1958.

In the experiment dealing with eggs, the treatments were designed to elicit information on the response of consumers to the price of grade AA eggs, grade A eggs and eggs aggregated over grades. Two treatments designed to provide information on the impact of a change in the amount of information concerning egg quality and uses were also included. None of the relationships estimated for eggs by grades were statistically significant at the five percent probability level. The change in the consumption pattern resulting from a change in the amount of consumer information was also not statistically significant. For eggs aggregated over grades a statistically significant relationship connecting average price of eggs and quantity disappearance of eggs per 100 customers was estimated. The elasticity estimate associated with this relationship was -1.15.

In the experiment dealing with T-bone steak, the pricing treatments were designed to provide price response information on Choice grade steak, Good grade steak and the aggregate of the two grades. In this experiment the variation among stores appeared important while the variation among treatment periods, or days, did not. A linear logarithmic relationship, significant at the five percent level, was estimated for the aggregate of T-bone steaks. The estimate of the point elasticity based on the aggregate relation was -2.09. A few significant relationships were also obtained for the individual grades of steak. For the Choice grade a logarithmic relation connecting the price of Choice T-bone with the quantity disappearance per thousand customers yielded a price elasticity estimate of -1.93. For the Good grade, a logarithmic relationship connecting the price of Good T-bone with the quantity disappearance per thousand customers (Choice grade steaks priced at 115 cents per pound) yielded a price elasticity estimate of -1.42.

For the experiment dealing with fresh fryers, the pricing treatments were designed to provide information on the response of consumers to changes in the prices of two types of fresh fryers. For this experiment the variation among stores did not appear important; variation among days appeared very important. No statistically significant relation was discovered between the average price of fryers and the aggregate quantity disappearance per thousand customers. A relationship was estimated connecting the price of cut-up fresh fryers and the price of whole fresh fryers with the quantity disappearance of cut-up fryers per thousand customers. Only the coefficient associated with the price of whole fryers, which yielded a cross-elasticity estimate of +1.49, was statistically significant. Three significant relationships were estimated for whole fryers. A relationship connecting quantity per thousand customers and price of whole fryers when cut-up fryers were priced at 47 cents per pound yielded a price elasticity estimate of -5.10; a similar relationship when cut-up fryers were priced at 55 cents per pound yielded a price elasticity estimate of -2.48. A relationship connecting the quantity of whole fryers per thousand customers with both fryer prices yielded a price elasticity estimate of -3.10 and a cross-elasticity estimate of +2.16.

Certain methodological conclusions may be warranted on the basis of the experience gained during the course of this study and the nature of the results obtained. On logical grounds there appear to be no reasons why controlled experiments would not generate data suited for the estimation of price-response relationships. In practice, however, factors such as the accuracy with which the variables can be measured and the degree of control which the investigator is able to exercise over the variables can influence the effectiveness of the technique.

Measurement errors in the three experiments reported are believed to be negligible because (1) prices were fixed whole numbers, (2) customer counts were taken from IBM cash register equipment and checked against counts from similar days, (3) quantity data for eggs and fryers were measured in discrete units, and (4) weight measurements were taken on modern scaling equipment in accord with a set of instructions given to store employees.

Several other factors which influenced the effectiveness of the experiments were the choice of treatments, choice of length of treatment period, and the adequacy of control over the price variables.

The results of the three experiments indicate that, for the most part, statistically reliable response relationships for specific grades of a product cannot be estimated on the basis of so few treatments. Remedies for this problem may include increasing the number of pricing treatments for a given grade of product, holding size of experiment constant or increasing the size of the experiment.

The choice of a single day as the treatment period was desirable in that a larger number of treatments could be handled in a shorter length of time. The selection of such a time period helped assure that many otherwise troublesome variables such as changes in seasons, effects due to advertizing, changes in the general level of prices, etc. would be effectively controlled. Such a choice of treatment period simplified the choice of an appropriate design. For the beef experiment the variation in days did not appear to be very important. Should such a situation prevail then a pricing experiment for T-bone steak conducted on Thursdays, Fridays and Saturdays could include an additional controlled variable. The results of the experiments are distorted to the extent that each treatment day fails to contain a representative sample of customers.

In each of the experiments control was granted over the prices of the products investigated. For the duration of each experiment the prices of products not under control remained constant relative to the changes in the experimentally controlled prices. In the fryer experiment the spread in price between types was greater than the spread within types. Since fryers represented the cheapest meat on a per pound basis an eight cent range in price was, perhaps, not adequate to register a response. In the fryer experiment control over a wider range of fryer prices would have been desirable.

An additional comment must be made concerning the control of variables. Although the analyses performed for the steak and fryer experiments did not provide tests of the variability among days and stores, the magnitudes of the mean square for days in the fryer experiment and for stores in the steak experiment accent the importance of ordinally measurable variables. In the egg experiment where the design did not permit statistical control of variation in days and stores, fewer significant results occurred.

Although income was assumed to be constant because of the duration of each experiment, gross store sales per thousand customers and the value of meat sales per thousand customers were included in the analysis. The coefficients associated with these variables were not, in general, statistically significant. In addition, the quantity disappearance of each of the products studied failed to change significantly under changing product price levels. These results imply that incomes did not vary significantly during the course of the experiments.

The results of the three experiments imply that controlled experiments provide a feasible method of generating data for the estimation of price-response relationships. The degree of success achieved in estimating response relationships for related products imply that controlled experiments provide a method of estimating cross-elasticities of demand at the retail level.

If research of this type were to be conducted extensively in the future, it is recommended that initially experiments be replicated until the desired level of precision is achieved. Upon achieving an acceptable level of precision, it may become feasible to expand such pilot studies to wider ranges of product types, to larger geographical areas, and to more extended periods of time.

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APPENDIX A

ANALYSIS OF VARIANCE FOR EGGS, ALL TREATMENTS

Appendix Table A.1

Source	d.f.	Sum of Squares	Mean Square	F	F_{05}	F_{01}
Total	314	7995.8645				
Treatments	8	152.3359	19.0420	2.30	1.97	2.58
Grades	3	4256.2624	1418.7541	171.43	2.64	3.86
Grade x treatment	24	478.2684	19.9278	2.41	1.56	1.87
Error	279	2308.9978	8.2760			

Standard Error of Grade Mean: 0.32

Standard Error of Treatment Mean: 0.48

Grade Means:

(AA)	(N.G.)	(B)	(A)
2.48	3.49	3.64	11.51

Treatment Means:

(3) (7) (1) (5) (8) (2) (6) (4) (9)

In Chapter III consideration was given to the relationships for eggs, in the aggregate and by grades, as generated by certain types of pricing treatments. An analysis of variance, including all pricing treatments, is given in Appendix Table A.1. The results of this analysis of variance indicate that treatments attained significance at the 5 percent level while grade and grade by treatment interaction attained significance at the 1 percent level.

The use of Duncan's Multiple Range test, however, reveals that treatment significance is due to a significant difference between treatments 3 and 9. Failure of the remaining treatment comparisons to attain significance may be attributed to the fact that the randomized blocks design, as used, was incapable of handling the variation due to store differences which remained inherent in the data.

APPENDIX B

Appendix Table B.1. Analysis of Covariance for Aggregate of Fresh Fryers

Source	d.f.	Sums of Squares and Products: Σy^2	Σxy	Σx^2	Errors of Estimate: d.f.	Sums of Squares	Mean Square	F	F_{05}
Total	53	1346.0555	11,763.5775	118,631.031					
Stores	4	37.4737	661.5433	13,904.734					
Days	10	1151.6842	9,876.8772	89,522.054					
Treatments (adj. for days)	10	17.0077	133.9047	2,347.729	10	10.9093	1.0909	0.646	2.19
Error	29	139.8899	1,091.2523	12,856.514	28	47.2652	1.6880		
Treatments + Error	39	156.8976	1,225.1570	15,204.243	38	58.1745			

Appendix Table B.2 Analysis of Covariance for Cut-up Fresh Fryers

Source	d.f.	Sums of Squares and Products Σy^2	Σxy	Σx^2	Errors of Estimate d.f.	Sums of Squares	Mean Squares	F	F_{05}
Total	53	526.7723	7,031.0160	118,631.031					
Stores	4	25.1037	564.7253	13,904.734					
Days	10	382.4702	5,563.6504	89,522.054					
Treatments (adj. for days)	10	34.9665	1,220.7023	2,347.729	10	28.9367	2.8937	2.21	2.19
Error	29	84.2319	781.9380	12,856.514	28	36.6741	1.3098		
Treatments + Error	39	119.1984	902.6403	15,204.243	38	65.6108			

Appendix Table B.3 Analysis of Covariance for Whole Fresh Fryers

Source	d.f.	Sums of Squares and Products Σy^2	Σxy	Σx^2	Errors of Estimate d.f.	Sums of Squares	Mean Square	F	F_{05}
Total	53	278.5273	4,736.1161	118,631.031					
Stores	4	2.1746	97.7986	13,904.734					
Days	10	216.9499	4,314.6143	89,522.054					
Treatments (adj. for days)	10	23.3714	14.1958	2,347.729	10	23.9308	2.3931	2.34	2.19
Error	29	36.0314	309.5074	12,856.514	28	28.5803	1.0207		
Treatments + Error	39	59.4028	323.7032	15,204.243	38	52.5111			

VITA

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