An Experimental Approach to the Estimation of Short-Run Price-Consumption Relationships for Eggs

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ERRATA

Page 19. In the third sentence of Section IV, subsection A, "quantity" should be quantify.

Page 20. In table 4.2, column headed "F_{01}" should be headed "F", and column headed "F" should be headed "F_{01}".

Page 28. The first two lines at the top of the page should be deleted.

Page 30. Appendix A. The test for grade means should be:

Grade Means:	(AA)	(N.G.)	(B)	(A)
	1.97	3.56	3.69	9.89

Page 31. Appendix C. The test for grade means should be:

Grade Means.	(N.G.)	(B)	(AA)	(A)
	2.17	2.94	5.78	14.44

Page 32. Appendix Table D.1. The multiple range for treatment means should be:

Treatment Means.

(3)	(7)	(1)	(5)	(8)	(2)	(6)	(4)	(9)
3.33	3.61	4.03	4.09	4.09	4.11	4.41	4.62	5.23

ACKNOWLEDGMENTS

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Preface

Knowledge relative to short-run price-consumption response relationships for eggs is a necessary prerequisite for intelligent action by a government or firm. This study is concerned with the possibility of using experimental observations as a basis for estimating these relationships. Although the study is to a large extent methodological in nature, it does present the results of applying a controlled experiment in estimating consumer response relationships for eggs.

CONTENTS

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I. INTRODUCTION

A. The General Problem Area

One practical purpose of research in quantitative economics is to provide the decision maker with "accurate" estimates of the future paths over time of each variable of interest corresponding to each alternative course of action. Within this framework, in a general operational sense, research in quantitative economics has a three-fold basis: First, to formulate economic hypotheses; second, to collect appropriate data; and, third, to confront hypotheses with data.[1] In this research, economic theory, statistical data and the modern methods of statistical inference combine to provide the tools for estimating the parameters of economic relationships. Given these tools as the foundation stones upon which estimation is to proceed, it is of paramount importance to realize that any statistical 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:[2]

"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

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

2 T. C. Koopmans and W. C. Hood, "Estimation of Simultaneous Economic Relationships", contained in *Studies in Econometric Methods*, New York: John Wiley and Sons, 1953, pp. 113-114.

control over these processes exercised by the scientist through experimental techniques. Finally there is the matter of measurement itself, the measure 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 others. In economics it is of much less significance than in most. But in all cases the choice and usefulness of a method of estimation or of testing hypotheses depend on the character (assumed or known) of the process of generating the observations."

Most of the studies concerned with the estimation of the parameters of behavior relations have used time-series data for which the sampling is performed by the historical course of economic phemomena outside of the investigators' influence. With this type of data, such terms as "unbiased estimate," "standard error of estimate," etc., have a meaning only in relation to an imagined sampling process. Time series data are therefore produced by the existing economic structure and, as such, the data are generated by systems of relations that are, in general, stochastic, dynamic, and simultaneous in nature. Occurring jointly, these three properties give rise to many unsolved problems of statistical inference from the observed data to the estimated relationships.[3]

Recent work in econometrics has stressed the importance of adapting statistical methods to the peculiarities of the data and the objectives of economic research. In spite of these advances, in many cases, the investigator has felt pangs of conscience when using time-series data as one of the foundation stones upon which parameter estimates are based. In addition, using these observational-type data, in most cases, leaves the possibility that we may be testing the theory on observations for which the theory was not meant to hold. Part of the confusion arises from the use of the same names for quantities that are actually different. Thus, we are constantly confronted with the questions: (1) Have we observed what we meant to observe, and (2) do the true variables actually have the properties of the theoretical variables?[4]

Given these restrictions, are there ways of generating data for our economic models other than the steady stream of experiments that nature turns out from her laboratory and which we, to a large extent, watch as passive observers? The answer to this question is, of course, yes, because the economist, when he specifies a system of relationships, usually has in mind some experimental design which could be arranged in order

3 Marschak, *op. cit.*, p. 3.
4 T. Haavelmo, "The Probability Approach in Econometrics", *Supplement to Econometrica*, Vol. 12, 1944.

to measure those quantities in the real economic world that potentially might obey the restrictions imposed on their theoretical counterparts. For example, in the micro-theory of consumer choice, it is postulated that the demand for a commodity is a function of the price of the commodity, the prices of other commodities, and the effective income of the consumer.[5] The design of experiments underlying this postulate 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 the action of the individual consumer in making his choice.

Probably the ideal method of verifying this hypothesis and reflecting the demand function involved would be to specify an experimental design such that the consumer would be confronted with alternative prices and levels of effective income and his reactions to the admissible situations tabulated. Assuming it is possible to conduct an experiment of this type and to generate a large number of observations by fixing the prices and income from experiment to experiment at alternative values (predetermined numbers), the observed reactions of the consumer would be a random variable—the stochastic properties of which would be defined by the distribution properties assumed for the residuals. 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 then possible to estimate the parameters of the functional relationship and the parameters of the distribution of the residuals.

It should be realized at this point that these estimates and the attendant prediction may be obtained by two logically 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 are 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 law of physics or chemistry are of this kind. The time required to boil an egg

5 M. A. Girshick and Trygve Haavelmo, "Statistical Analysis of the Demand for Food," *Econometrica*. Vol. 15, 1947, pp. 79-110.

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 . . . "[6]

If one examines some of our current economic theories, it is apparent that experimental data of the type mentioned above would be required to test many of these theories. However, in most cases, the kind of economic data we actually have comes from the passive observation of reality. The result is that theories are often compared with observations that do not reflect the variables which the theorist originally had in mind.

These considerations point up the importance, in quantitative economic research, of considering the conditions under which the observations are produced before identifying them with the variables of a particular theoretical model. It also suggests, as a means of coping with the data problem, the possibility of experiments or controlled measurements designed to obtain the real variables for which the investigator thinks his model would hold if other influences were artificially isolated.

B. Specific Problem Area

Within the framework discussed under the general problem area, the major objective of this study was to employ observations generated from a controlled experiment in estimating the parameters of the short-run price-consumption relationships for eggs. The purpose of this type research, concerned with estimating the parameters of specified relationships, is to be able to predict, with a certain degree of probability, the economic results of decisions in order to lay before those responsible for choice the consequences of alternative courses of action. I.e., if the quantitative characteristics of the models to be specified can be obtained, it is possible to forecast with a specified level of probability the path of certain magnitudes, such as consumption, under specified conditions. Such knowledge of the parameter estimates is a prerequisite for intelligent action by a government or firm.

The specific objectives delineated for this study included: (1) Estimation of the short-run price-consumption relationship for all eggs, (2) estimation of the short-run price-consumption relationships for eggs by grades, (3) estimation of the preference of consumer by grades when price is not a factor in their choice, and (4) estimation of the impact of

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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 page 292.

consumers' information, relative to grade characteristics and uses on their choice by grades.

A corollary objective of the study was investigation of the practicability of employing controlled experiments as a means of generating data from which short-run price-consumption relationships may be estimated. This study should also be of value in bringing to the attention of model builders the fruitfulness of specifying an attendant design of experiment for their theoretical constructs.

II. THE ECONOMIC MODELS

The economic models to be presented represent an attempt to describe, in simple form, the relationships existing in the real world between consumer preferences for eggs and the monetary values placed on these preferences. Basically, the models attempt to specify short-run price-consumption relationship for eggs. Within this framework, the models are designed to explain the behavior patterns of consumers in the aggregate when their basic preferences are conditioned by changing price structures in the market or by an increased amount of consumer knowledge concerning a single grade factor. Selection of the admissible models is conditioned by the present state of knowledge concerning the behavior patterns of egg purchasers and the lack of any set of optimum criteria permitting a choice among the competing alternative models. Therefore, the ensuing models are postulated on the basis of the existing body of economic theory and modified by certain *a priori* knowledge which is generated by observation and by certain restricting assumptions.

In order for data to be generated that reflects 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 knowledge (though not necessarily complete knowledge) to make these criteria operational. Within this framework, several admissible models concerning the reactions of consumers of eggs to certain stimuli are specified and the design of experiment, which is an essential appendix to any quantitative theory, is discussed.

A. Basic Consumer Preferences

At the outset, in order to establish a reference datum, a model depicting consumer preferences devoid of any effects of market stimuli may be a necessary step. For the commodity eggs, this model may be posulated as:

$$y_{ij} = f(z_{1j}, z_{2j}, z_{3j}, z_{4j}, z_{5j} \ldots z_{nj}), \qquad (2.1)$$

where y_{ij} represents the quantity disappearance of eggs; z_{1j}, a measure of interior quality; z_{2j}, a measure of shell color; z_{3j}, a measure of egg size; z_{4j}, the type of carton; and z_{5j}, a measure of the cleanliness of the eggs.

This model is a conceptual model and no attempt was made to estimate the parameters involved. Instead, a datum was established for a single preference factor, interior quality, by recording a single observation of the quantity disappearance of each quality level when all other primary decision making factors are held constant.

Another preference factor, shell color, was investigated by offering consumers a single quality level (grade A) in both white and brown shells while all other decision making factors remained constant.

B. Consumption as Modified by Price Differentials

Consumers generally are not faced with the problem of making decisions based solely on their preferences. More frequently, additional factors enter into the decision-making process. One of the more important economic factors among this group is the price of eggs. Consequently, a model describing the reactions of consumers of eggs when price is included as an artificially isolated factor in their set of decision-making criteria may be postulated as:

$$y_{1t} = f(p_{1t}, z_t; \alpha_1, \alpha_2 \ldots \alpha_k) + u_t, \quad (2.2)$$

where y_{1t} represents the quantity disappearance of all eggs per 100 customers; p_{1t} represents the average retail price of all eggs; and z_t, pre-determined levels of other variables. $\alpha_1, \alpha_2 \ldots \alpha_k$ are constants to be estimated, and u_t is a random residual, the economic meaning of which is that given a set of prices, consumers do not behave in the same way either because other relevant variables were omitted from control or because individuals are not always consistent in their behavior.

This model serves a dual function in that modifications in consumer preferences resulting from a uniform change in the price of all subclasses of the commodity may be measured and compared with the modifications due to a non-uniform change in the price of one or more of the various subclasses.

Consumer demands are not completely satisfied by providing them with eggs per se. As was postulated in equation 2.1, consumers differentiate on the basis of many preference factors. In general, one of the most important factors consumers utilize 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. Thus, a model portraying consumers' willingness to pay for the preference factor, interior quality, may be postulated as:

$$y_{2t}=f(p_{2t}, z_t; \alpha_1 \ldots \alpha_k)+u_{2t}, \quad (2.3)$$

where y_{2t} represents the quantity disappearance of the preference factor, interior quality, as measured by the quantity disappearance per 100 customers when other preference factors are held constant experimentally; p_{2t} represents the retail price of the given preference factor; z_t represents other predetermined variables, and u_{2t} is again a random residual.

C. Consumption as Modified by Improved Consumer Knowledge

Since consumers must make decisions regarding the purchase of an extremely large number of goods and services and are operating under the restriction of a limited amount of time, the degree to which perfection can be attained concerning knowledge of the attributes of these goods and services is set at an extremely low level. Although for any one good some consumers may closely approach the status of complete knowledge, this is not likely to be the case in the aggregate.

Under the hypothesis that consumer satisfactions may be increased with additional information concerning a product, a model designed to measure the impact of such information might be constructed such that the quantity disappearance of a preference factor is a function of the amount of knowledge concerning that factor. However, due to the difficulty that would be encountered in an attempt to formulate a variable capable of cardinally expressing changes in the degree of knowledge possessed by a group of consumers, some alternative means of attaining the same result would appear to be desirable.

One alternative employed in this study sought to measure indirectly the magnitude and direction of change in consumer preferences when additional information was supplied. This was done by a comparison of the preference datum with a treatment similar in all respects to the datum except that consumers received additional information concerning the attributes of the product.

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

Economic theory postulates that the demand for a good is contingent on the price of the good, the prices of competing goods, the price of all other goods, and disposable income.

From an operational standpoint, an income variable may be very difficult and expensive to obtain. In view of this situation, an alternative variable serving the same purpose was advisable. Gross store sales, deflated by number of customers, may be such a variable. A model describing the behavior of consumers of eggs which considers this additional variable may then be postulated as:

$$y_{3t}=f\,(p_{3t},\ x_t,\ z_t;\ a_1\ .\ .\ .\ a_k)+u_{3t}, \qquad (2.4)$$

where y_{3t} represents the quantity disappearance of all eggs per 100 customers; p_{3t} represents the average retail price of all eggs, and x_t represents the gross sales per 100 customers.

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

$$y_{4t}=f\ (p_{4t},\ x_t,\ z_t;\ a_1\ .\ .\ .\ a_k)+u_{4t} \qquad (2.5)$$

where y_{4t} represents the quantity disappearance of a particular grade of eggs, p_{4t} represents the retail price of that grade, and x_t represents the gross sales per 100 customers.

E. Changes in Distribution of Sales Arising from a Price Change in A Single Grade

Since all the 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.

Based on such a premise, the following model was postulated as a measure of the degree of competition among the various grades.

$$y_{5t}=f\,(p_{5t},\ p_{6t},\ z_t;\ a_1\ .\ .\ .\ a_k)+u_{5t} \qquad (2.6)$$

where y_{5t} represents the quantity disappearance per 100 customers of a particular grade of eggs, p_{5t} represents the price of the particular grade, and p_{6t} represents the price of one of the competing grades.

This brief statement concludes the specification of the models which were estimated. Many possible alternative variants of the models remain. However, the specifications presented are believed to be a plausible set of models.

III. THE EXPERIMENTAL DESIGN AND THE SETTING

A. Choice of a Design

Given the economic models specified in the previous section, it is now in order to consider the data that will best reflect the variables specified. Most studies concerned with estimating price response relationships have utilized data to reflect their postulated variables that were automatically generated by the market mechanism of the economy. The shortcomings of this type of data have led many engaged in quantitative economic research to speculate on the use of controlled experiments which would consist of deliberately fixing the price at various values and observing the results. Of course, the cost of such an experiment as this for the economy as a whole would be prohibitive. However, the problem takes on more practical aspects when the universe is partitioned into smaller units, such as small geographical areas or communities. For example, let us assume it is possible to conduct an experiment concerned with the responsiveness of consumption (y_t) to price (p_t) in some small community.[7] Under this framework the random variables p_t would be replaced by constants p_t^* (i.e., the prices from experiment to experiment would be *fixed* at varying values). Denoting other predetermined variables by z_t, we can then define

$$y_t = f\ (p_t^*,\ z_t;\ \beta) + u_t \qquad (3.1)$$

In order to proceed, the u's must have some properties that are predictable on the average. One way of proceeding is to assume the u's are stochastic variables that have certain characteristic distribution properties. The conditional mean and variance of the predictand, y_t, are functions of the given values of the predictor set (p_t^*, z_t) :

$$\mu y_t = E\ (y_t/p_t^*,\ z_t) = f\ (p_t^*,\ z_t;\ \beta), \qquad (3.2)$$

$$\sigma_{yy} = E \left\{ (y_t \text{-} \mu_{yt}{}^2 \middle| p_t^*\ z_t) \right\} = \sigma_{uu}. \qquad (3.3)$$

We can then proceed to obtain unbiased and efficient estimates of β and σ_{uu} from the observations by minimizing $\sum_{t=1}^{T} u_t^2$ with respect to β and σ_{uu} (the method of least squares).

Examination of the economic models presented in the previous section suggests a need for an experimental design which will artificially isolate certain phenomena from other influences in order that the parameters of the specified relationships may be estimated and certain hypotheses tested. If the use of controlled experiments is to fulfill the purpose of generating the type of data specified by present economic theory, then it is incumbent upon the economist to choose a design that will accomplish this end in the most efficient manner. The number of alternatives open to an investigator is a function of the complexity of the relationships to be estimated. For any particular problem, economic theory

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7 J. Marschak, "Statistical Inference from non-Experimental Observations: An Economic Model," *Proceedings of the International Statistical Conference,* 1947 Vol. III, pp. 292-93.

linked with *a priori* knowledge specifies almost innumerable variables for inclusion in any given relationship. Therefore, in order to study the relationship among a limited number of these variates, the movements of all other variables must be subjected to the *ceterus paribus* condition by either physical or statistical control. Consequently, the number of variates which can be subjected to physical control will be an important determinant in the choice of a design. In exploratory work, care must be taken in the choice of variables to be held constant. Unless there truly exist no interactions among the variates under study and those held constant, these interactions will appear in the error term and may appreciably reduce the ability to detect significant results when they exist.

B. Design Used

In general, an investigator has a large 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 economic research, the large number of factors that usually must be considered suggests the use of one of the incomplete block designs. In some instances, however, the experimental conditions may be suited to the use of one of the simpler designs such as the Latin square or randomized blocks. The Latin square provides a logical choice, since it combines simplicity with a large measure of control and has been used successfully by Godwin, Dominick and others in similar research.[8]

Despite the advantages of the incomplete block designs and the Latin square design, a randomized blocks design in conjunction with a factorial arrangement of treatments was used in this study largely as a consequence of policy restrictions of the retail chain.

The use of this design for this study defines the following model:

$$y_{ijk}=m+p_i+g_j+r_k+e_{ijk}, \qquad (3.4)$$

where y_{ijk} represents the disappearance of eggs in dozens per 100 customers, m represents the over-all 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 constitutes the smallest feasible time unit. In view

8 M. R. Godwin, "Consumer Response to Varying Prices for Florida Oranges", University of Florida Agricultural Experiment station, Bulletin 508, 1952.

B. S. Dominick, Jr. "Methods of Research in Marketing", Paper Number 2, Cornell University Agricultural Experiment Station, 1952.

A. W. Jasper, "Increasing Sales of Fresh Fryers Through Improved Merchandizing Practices", Cornell University Agricultural Experiment Station, A. E. 954, 1954.

of the number of treatments incolved, two sources of time variation could enter the error term. The first of these, variation between days within weeks, was handled by choosing two similar shopping days within a week. The second of these, variation among weeks, was uncontrolled and assumed negligible.

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 to which the shift takes place. However, acceptance of an immediate purchase is usually proportionate to the income effect of alternative action. Therefore, with a commodity such as eggs, the income effect is probably small and a decision on alternative action is relatively minor.

A second criticism arises because of the delayed and sluggish response of consumer purchases to price.[9] Therefore, the age or length of each treatment becomes of paramount importance. Experimental designs incorporating provisions for the measurement of carry-over effects offer a partial solution to this problem.

In addition, it should be noted that estimates from studies such as this refer to elasticities facing retail outlets and do not indicate the elasticity of consumer demand for a product in the conventional sense.

C. 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 the sample. 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. Such a choice permitted the sample to include a wide range of income classes, families of varying size, and diverse racial and religious factions, as well as many other unspecified factors. In addition to the above advantages, the choice of a city such as Tulsa permitted greater administrative control over the experiment than could be obtained if several smaller cities had been sampled.

9 Mimeographed material of a preliminary study on age of treatment conducted by University of Florida Agricultural Experiment Station by Marshall R. Godwin.

Within the city, eleven large, modern, self-service markets operating under the management of a single prominent chain of retail outlets were selected. The stores were located in such a manner that the sampling took place throughout the entire city. These stores also 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, a degree of control over the quality factor approaching the optimum was achieved.

Since all of the stores in the experiment did not handle the same grades and sizes of eggs, it was necessary to establish a display standardized for all stores as to these two factors. On the basis of normal store stocks and the availability of adequate supplies, this standardization consisted of a non-graded egg and the three top grades as determined by U.S.D.A. standards (AA, A, B). The graded eggs were used in the large size only.

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 deemed sufficiently alike to constitute a homogeneous population and permitted the effects of time within weeks to be eliminated. (2) Selection of these two days provided the location managers the remainder of the week in which to adjust their 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 the egg sales), a maximum amount of information could be obtained at a minimum 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″x9″ placards designating the grade, size, and price. A departure from this procedure was made during Treatment 9. For this treatment, the placards designated the grade, size, and price and, in addition, displayed colored photographs of the three top grades in the hard-cooked 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 prearranged schedule.

Pricing of the eggs was varied according to the design indicated in Table 3.1.

Treatments 1 through 3 were designed to measure the changes in

Table 3.1.—Pricing treatments for Tulsa retail egg experiment

	Grade			
Treatment	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

consumer responses for the various grades of eggs under a uniform price level rise as postulated by model 2.2.

Treatments 1, 4 and 5 were designed to measure consumer responses for grade AA eggs under static conditions, while treatments 5 through 7 performed a similar function for grade A eggs through the application of model 2.3.

Treatment 8 was designed to generate the data to test model 2.1 (basic preferences), and Treatment 9 was used to provide data for testing the effects of added consumer knowledge concerning the grade and respective uses of eggs.

Regardless of the care exercised in designing a controlled experiment, 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 these problems, the following procedures were employed:

Approximately one week prior to the initiation of the experiment, 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 avoid an inadvertent error in pricing, only pricing information sufficient to facilitate ordering was released to store personnel in advance. In the event that needs were not accurately anticipated and shortages appeared, liason 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 each store as well as blank forms for recording an inventory of sales for each treatment.

D. The Need and Use for a Pilot Experiment

The success of any attempt to statistically measure the parameters of the economic relationships postulated in Section II is contingent upon the wise choice of design and the number of replications associated with the chosen design.[10]

The choice of design is largely determined by the objectives, the nature of the experimental material, and the type of treatments to be applied. In addition, administrative considerations may impose many other restrictions on the final choice of design. The number of replications necessary to detect a significant difference, when one exists, is a function of the true difference and the true standard error per unit. Since these two values are generally unknown, some estimate of each is necessary before a decision can be reached regarding the number of replications to be used.

One means of obtaining such estimates is through a careful review of prior research of the same nature. In some instances, however, the nature of the research is such that no prior estimates are available. In other instances, estimates are available, but not applicable because the experimental unit may not be the same. This may be caused by the fact that the prior work was conducted in a remote time period or area where incomes, technology and social mores may be vastly different from that being contemplated.

A second means of obtaining estimates is by means of pilot studies. In the case where no previous estimates are available, the need for a pilot study is obvious. In the second situation, even though the available estimates may be valid, it may still be desirable to conduct a pilot study to test the administrative aspects of the study. Experience has shown that many of the difficult problems involved in the operation of a controlled experiment center on the ability to detect and adequately handle the administrative details. Of course, to insure that the pilot study accomplishes its purpose, care must be exercised to insure that the experimental

10 The use of one of the more complex designs may severely restrict the freedom of choice in the number of replications to be used.

material treated in the pilot experiment is as nearly like the material to be treated in the full scale study as is possible.

A pilot experiment preceded the Tulsa study, and the information obtained was invaluable in carrying out the major experiment. Over and above being an aid in ironing out administrative difficulties, the pilot study provided necessary information relative to the time unit of observation and operational price differentials.

IV. THE EMPIRICAL RESULTS

It is now in order to confront the postulated models with the data generated from the controlled experiment. At the outset, emphasis is directed toward the exploratory nature of the study and results. In this section, each of the postulated models is estimated and subjected to economic and statistical tests and the results interpreted. In each case where short-run price-consumption relationships are 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 a demand for a product. Also, it should be kept in mind that any inferences drawn refer only to the geographical area represented by Tulsa, Oklahoma. In many instances, because of the limited number of observations, the results should be interpreted as point estimates.

A. Basic Preferences

Preferences for different defined qualities of a good may be accepted at the outset or else they may be established by a simple experiment in which price is not a factor. In this study, it was deemed desirable to initially investigate the basic preferences structure for eggs as it relates to interior quality. Although no attempt was made to quantity the parameters of model 2.1 a rough estimate of this preference structure was obtained through the measurement of the quantity disappearance of each grade. To accomplish this purpose all other factors affecting choice, except interior quality, were held constant. The results of this procedure are presented in Table 4.1 and an analysis of variance of the data generated is given in Table 4.2.

As could be expected when price is not a factor, the major portion of the purchases was associated with the grades A and AA. Purchases of the A grade eggs amounted to 62 percent of total sales, overshadowing the other three grades available. The analysis of variance, supplying the statistical tests to these data, indicates that the consumers involved made decisions regarding two types of eggs—grade A and others. Consumers were indecisive about the meaning of the grade AA egg classification.

Table 4.1.—Basic preference structure for eggs as determined by interior quality

	Grades					
	AA	A	B	Nongraded	A_w	A_b
Mean dozen sales per 100 customers	3.77	13.74	2.65	1.95	6.34	7.40
Percent of total treatment sales	17.05	62.13	11.99	8.83	28.67	33.46

Table 4.2.—Analysis of variance of basic preference structure

Source	d.f.	Sum of Squares	Square Mean	F_{01}	F
Total	40	399.4238			
Stores	8	95.5342			
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:	(N.G.)	(B)	(AA)	(A_w)	(A_b)
	1.95	2.65	3.77	6.34	7.40

This and the fact that grade AA sales amounted to only 17 percent of total sales are surprising but may possibly be attributed to the fact that consumers were not aware of the attributes associated with this grade of eggs. Sales of grade B and non-graded eggs made up a small portion of total sales; and choices relating to these grades may again be due, in part, to incomplete information possessed by consumers. Rudimentary evidence is also presented in Tables 4.1 and 4.2 to support the hypothesis that there is no marked discrimination among consumers in regard to shell color.

B. Effects of Price Level Changes

In order to include price as a decision-making factor and to ascertain the impact of this factor on the structure and on total consumption of eggs, pricing Treatments 1, 2, and 3 were employed. (See Table 3.1 for the level and structure of these prices.) Under this procedure a sevencent price differential was fixed between grades and between treatments with a linear increase in price between Treatments 1 and 3.

The results of these treatments are presented in Table 4.3 and compared with the treatment relating to basic preferences when price was not included as a choice factor.

Table 4.3.—Structure of egg sales under alternative levels of prices

	Grades AA	A	B	No Grades	Total
			percent		
Basic preferences	17.05	62.13	11.99	8.83	100
Treatment 1	10.68	51.17	20.25	17.90	100
Treatment 2	8.80	53.37	21.52	16.31	100
Treatment 3	7.87	45.08	23.42	23.63	100

When price is included as a choice factor, a percentage decrease in the consumption of AA and A grade eggs and a percentage increase in the consumption of B and non-graded eggs were apparent. Examination of the changes in the percentage distribution of egg purchases among the three level treatments indicates the somewhat systematic manner in which consumers shift from grade AA to the competing grades and then finally from both top quality grades to B and non-graded eggs.

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 1. In constructing Figure 1, each relationship is considered the ordinate for the succeeding response function. In absolute terms, the relationships for B and non-graded eggs are completely inelastic and, therefore, indicate a constant rate of purchase over the three treatment prices. The relationships for both AA and A grade 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. The inelastic B and non-grade relationships probably obtain due to: (1) A decrease in purchases by regular consumers of B and no-grade as price increases, and (2) a substitution of these grades by consumers of AA and A grade as the price of these grades increases—the income and substitution effects thereby canceling each other. As a basis of comparison, cumulative purchases by grades for the basic preference treatment are denoted in Figure 1 by asterisks.

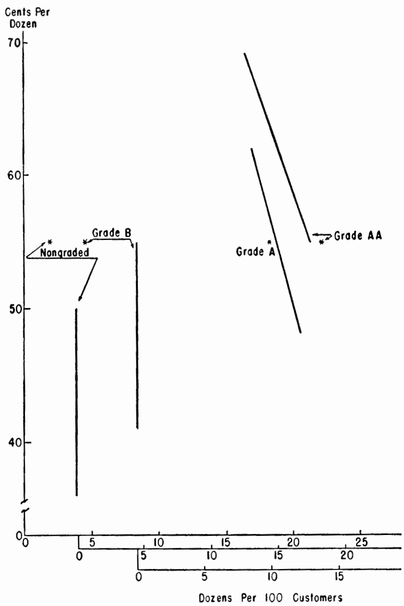

Figure 1.—Linear price—consumption relationships for eggs by grades under three price level treatments.

Analysis of variance of the data obtained in these treatments is given in Appendix A.

C. Short-Run Price-Consumption Response Relationships

Given the data relating to basic preferences for eggs and the level and structure of egg purchases when price is a factor, it is now in order to use the data generated from these and other treatments as a basis for estimating the parameters of the short-run price-consumption relationships, first for all eggs and then by grades.

Response relationship for all eggs.

In order to obtain parameter estimates of the short-run price-consumption relationship for all eggs, alternative groupings of the treatments were utilized. Initially, consider the situation reflected by Treatments 1, 2 and 3 (constant price differential between grades and a linear increase in price between treatments). In order to derive an estimate of the relationship between the purchase of eggs and price, a linear model was postulated. Estimation of this linear model resulted in the following regression equation:

$$y_1=33.91-0.2757z_1, \qquad (4.1)$$
$$(0.1808) \qquad R^2=0.70.$$

where y_1 represents the total purchases of eggs in dozens per 100 customers and z_1 represents the average price of eggs per dozen. In this and in succeeding analyses, standard errors of estimate appear in parentheses below the coefficient. The sign of the coefficient agrees with logic in that as the price of a superior good rises consumption declines. Use of equation 4.1 results in an estimate of the price elasticity of retail demand, at the means of the variables, of -0.73. Utilizing the extreme coordinates of the function (within the confines of the data) yielded price elasticity of retail demand estimates of -0.96 and -0.60.

As an alternative specification for the price-consumption relationship for all eggs, observations generated by Treatments 1 through 7 were utilized. This specification thus involved data generated by changes in the level of price and a change in the price of one or two grades of eggs. Utilizing this data, a linear model connecting egg purchases and price was postulated. Estimation of this model resulted in the following regression equation:

$$y_1=45.07-0.4764\ z_1 \qquad (4.2)$$
$$(0.1072) \qquad R^2=0.80$$

where the variables take on the same definitions as in equation 4.1. Again the sign of the coefficient agrees with logic, and a point estimate of the price elasticity of retail demand at the means of the variables of -1.15 resulted. Utilizing the extreme price and quantity coordinates of the function yielded price elasticity of demand estimate of -1.22 and -0.91.

Utilizing the same data and postulating a model linear in the logarithm of the variables resulted in the following regression equation:

$$\log y_1=3.39-1.2197\ \log z_1 \qquad (4.3)$$
$$(0.2638) \qquad R^2=0.81$$

This relationship, of course, implies a constant elasticity over the range of the function of -1.22.

Since past prices might be an additional source of information for decision making purposes, a model linear in the variables, average price per dozen (z_1) and the difference between the average price per dozen in time period t and the average price per dozen in the time period t-1

(z_2), was specified. This model was estimated with the following result:

$$y_1 = 45.77 - 0.4829\ z_1 - 0.0873\ z_2, \qquad (4.4)$$
$$(0.1340) \quad (0.0271) \qquad R^2 = 0.93$$

This relationship reflects an estimate of the price elasticity of demand at the mean of -1.19. Utilizing extreme values of the function resulted in elasticity estimates of -1.26 and -0.93. This relationship also calls attention to the impact of past prices on the purchase of eggs in time period t.

In summary, it should be noted that the signs of the cofficients are consistent with the theory underlying each model. As would be expected from the nature of the data used, price elasticity estimates from models 4.2, 4.3, and 4.4 differ from that of 4.1 in terms of magnitude. The appropriate choice between models should be conditional upon the conditions that are attempting to be reflected.

Price-consumption relationships by grades.

In many cases, knowledge of the price consumption relationships for all eggs is not sufficient. For certain economic considerations, a knowledge of the response relationships by grade is required. As mentioned earlier, certain of the treatments were designed to isolate the response relationships for AA and A grade eggs. These treatments were designed to obtain the reaction of purchasers to alternative prices for a given grade when all other prices are held constant. Consequently, the response relationships derived are subject to only one set of prices for the other grades and should be interpreted with this restriction in mind.

Response relationships for AA grade eggs. In order to estimate a response relationship for AA grade eggs, data generated by Treatments 1, 4 and 5 were employed. Utilizing this data, a linear model connecting the purchases and price of AA grade eggs was postulated. Estimation of this model resulted in the following regression equation:

$$y_2 = 6.70 - 0.0693\ z_4, \qquad (4.5)$$
$$(0.0136) \qquad R^2 = 0.96$$

where y_2 represents the consumption of AA grade eggs in dozens per 100 customers and z_4 represents the price of AA grade eggs in cents per dozen. The sign of the coefficient connecting purchases and price agrees with economic preconception. Use of this relationship results in a point estimate of the price elasticity of retail demand at the mean of -1.78, therefore implying an elastic response to price for this commodity. Utilizing the extreme coordinates of the function yielded price elasticity of demand estimates of -2.49 and -1.32. Although the study was not designed to ascertain the degree of competition between grades of eggs, the data generated by these three treatments did indicate a substitution of grade A for grade AA eggs as the price of the latter increased.

Although it cannot be considered a demand relationship in the classical sense, it may be of interest to present an estimate of the response relationship for AA grade eggs generated by Treatments 1, 2 and 3. It should be noted that in these treatments the prices of all others were not held constant as in the previous analysis. Utilizing this data with a linear model resulted in the following regression equation.

$$y_2 = 6.43 - \underset{(0.0107)}{0.0729}\, z_4, \qquad R^2 = 0.98 \tag{4.6}$$

It is interesting to note the agreement in the magnitude of the coefficients connecting y_2 and z_4 in equations 4.5 and 4.6. Although the rate of change between the two variables is approximately the same for the two equations, a difference obtains in the level of purchase. Therefore, equation 4.6 resulted in a price elasticity of retail demand estimate at the mean of -2.26.

Response relationships for A grade eggs. As the basis for estimating a response relationship for A grade eggs, data generated by Treatments 5, 6 and 7 were employed. Given this data, a model linear in the variables, purchases and price, was postulated. Estimation of this model resulted in the following regression equation:

$$y_3 = 22.62 - \underset{(0.0388)}{0.2286}\, z_5, \qquad R^2 = 0.97 \tag{4.7}$$

where y_3 reresents the consumption of grade A eggs in dozens per 100 customers and z_5 represents the price of grade A eggs in cents per dozen. Again, the sign of the coefficient connecting the two variables agrees with logic. Use of this relationship results in a point estimate of the price elasticity of retail demand at the mean of -1.25, again implying an elastic response to price for this commodity. Using the extreme coordinates of the data yielded price elasticity of retail demand estimates of -1.69 and -0.94.

Using the same data and postulating a model linear in logs resulted in the following regression equation:

$$\log y_4 = 3.15 - \underset{(0.1109)}{1.2400} \log z_5 \qquad R^2 = 0.99 \tag{4.8}$$

This equation, of course, implies a constant elasticity over the range of the function of -1.24. Both models yield a good fit to the data; however, in this regard, equation 4.8 is slightly superior. Although additional data would be necessary to test the extent of substitution beween grades as price ratios change, the data generated by Treatments 5, 6 and 7 did lend support to the hypotheses that B and no-grade eggs are substituted for A grade eggs when the price of the latter increases.

As in the case of grade AA, it may be of interest to consider the grade A response relationship reflected by price level Treatments 1, 2 and 3. Again, attention is called to the fact that the prices of the other grades of eggs were not held constant in these treatments. Using this data with a linear model resulted in the following regression equation:

$$y_4 = 24.57 - \underset{(0.2078)}{0.2571}\, z_5, \qquad R_2 = 0.60 \qquad (4.9)$$

Again, it is interesting to note the agreement in the size of the coefficients connecting the variables in equations 4.7 and 4.9. Equation 4.9 resulted in a price elasticity of retail demand estimate at the mean of -1.17. Using the extreme coordinates of the data yielded price elasticity estimates of -2.05 and -1.08.

Response relationships for Grade B and non-graded eggs. Although the study was not specifically designed to measure the response relationship for grade B and non-graded eggs, it may be instructive at this point to use the data generated by the experiment to obtain an estimate of this relationship. Since there is some indication that A grade eggs substitute for B and non-graded eggs under certain price conditions, a model linear in the variables connecting these prices and the purchases of B and non-graded eggs were postulated. Estimation of this model resulted in the following regression equation:

$$y_5 = 8.49 - \underset{(0.0627)}{0.1680}\, z_6 + \underset{(0.0548}{0.1380}\, z_5, \qquad R^2 = 0.67 \qquad (4.10)$$

where y_5 represents the aggregate consumption of B and non-graded eggs in dozens per 100 customers, z_5 the price of grade A eggs in cents per dozen, and z_6 the average prices of B and non-graded eggs in cents per dozen. Because of the underlying experimental design, no strong inferences are possible from the above relationship. However, the signs of the coefficients connecting the variables are consistent with the theory underlying the model. Use of this relationship yielded a crude point estimate of the price elasticity of -0.8125 and a price elasticity of substitution estimate of 0.8205. This relationship implies an inelastic response to price for these grades and indicates the impact that the price of a substitute good (grade A) has upon the purchases of these grades. The results of this relationship lend support to the conditions reflected by Figure 1 and Table 4.3.

D. Impact of Consumer Information on Choice

In most cases the choices that consumers make in the market are restricted by imperfect information as to the attributes of a commodity. 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 rudimentary effort might provide an insight into the impact of level of information on choice. Using Treatment 8 (basic preferences) as a basing point, application of Treatment 9 generated the results presented in Table 4.4.

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 the higher quality eggs. The major shift was from A to AA grade eggs, with minor shifts from the B and non-graded eggs. The analysis of variance for this treatment (given in Appendix C), however, indicates that the magnitudes of the shifts are not significant to a degree to distinguish it from the basic pattern of choices. This is one problem area where the age of the treatment is probably of great importance. There is undoubtedly some stickiness in terms of the information being reflected in choices.

Table 4.4.—Impact of level of information on choice

	Grade				
	AA	A	B	Non-Graded	Total
			Percent of Total		
Basic Pattern	17.05	62.13	11.99	8.83	100.00
Added information	22.18	57.48	11.66	8.68	100.00
Net movement	+5.13	—4.65	—0.33	—0.15	0.00

V. IMPLICATIONS OF THE RESULTS

Although this study was exploratory in nature and a final invariant statement regarding the results is impossible, certain conditional inferences based on the estimated relationships may be warranted at this time. If it can be assumed that the estimates given in the preceding section are accurate portrayals of the parameters of the postulated models, then they dozen, and z_6 the average prices of B and non-graded eggs in cents per dozen, ,and z_6 the average prices of Z and non--graded eggs in cents per provide a basis for analyzing the impact of alternative courses of action by a government or firm. From an economic policy level, the price elasticity parameter estimates for all eggs may be used to gauge the impact of total supplies on total revenue. However, here it should be remembered that these estimates apply only to a restricted geographical area and consumer responses refer to purchases at retail outlets.

A. Implications for Retail Firms

For inferences pertaining to the retail firm, selected estimated relationships will be analyzed to suggest their possible uses. First, assume that a certain retail organization is the sole supplier of eggs to a given restricted geographical area. Assume further that the objective of the retail chain is to sell the quantity of eggs and charge the price that will make profits as large as possible. Also assume that the retail organization buys eggs in a perfectly competitive market and can therefore obtain any quantity of eggs at a constant price.

In order to see how a retail organization working under these assumed conditions might achieve the maximum profit objective, consider equation 4.2 which refers to the relationship for all eggs. This equation can be converted to an average revenue function for all eggs which is:

$$P=94.60 - 2.10\ q, \qquad (5.1)$$

where P is the average price for all eggs and q is the quantity purchased in dozens per 100 customers. Now assume that the retail organization pays an average price of 35 cents per dozen for all eggs bought from the supplier, implying the following average cost function:

$$C=35, \qquad (5.2)$$

where C represents average cost per dozen. From equations 5.1 and 5.2, total revenue and total cost functions can be obtained and then converted to marginal revenue and marginal cost functions. Under these conditions and employing the familiar maximizing rule, in order for profit to be a maximum, marginal cost must be equal to marginal revenue. By equating these two functions, it is then found that in order for the retail organization to maximize profit under these postulated conditions, an average price of 65 cents per dozen would be charged for eggs and at this price consumers would purchase 14.5 dozens per 100 customers. By considering other possible egg costs, alternative prices and quantities that will maximize profit can be obtained by employing the above procedure.

Alternatively equation 5.1 can be used to gain an answer to the problem: Given a certain quantity of eggs to be sold, what price should be charged in order to dispose of the eggs? For example, suppose the retail organization wanted to sell on the average 16 dozen eggs per 100 customers. Then by using equation 5.1 an average price of 61 cents per dozen would be required to move this quantity of eggs.

Another problem that might be analyzed is the following: Given a certain price to be charged for eggs at the retail level, how many eggs should be purchased by the retail organization to fulfill the demand of consumers? To answer this question, equation 4.2 could be used. An estimate of the supply in dozens to purchase per 100 customers could be obtained by inserting the average price of eggs (z_1) into the equation and solving for the average purchase at this price.

Analyses similar to that for all eggs could be made by grades. For example, in regard to AA eggs, equation 4.5 could be used and converted to an average revenue function. Assuming then certain supply prices (say 47 cents per dozen) for AA grade eggs, it would be possible to compute the price and quantity (in this case a price of 72 cents and quantity 1.7 dozen per 100 customers) that would maximinize profit from the sale of this grade. Alternatively, given a certain supply of eggs, the average revenue function could then be used to estimate the price that would be required to move this quantity of AA eggs. In addition, if the average retail price of AA grade eggs were predetermined, equation 4.5 could be used to estimate the supply that should be obtained by the retail organization. Similar analyses could be made for A, B, and nongraded eggs.

B. Methodological Implications

Although from a methodological standpoint this study was exploratory in nature, it does support the use of controlled experiments as an operational procedure in deriving short-run price-consumption relationships. Because of restrictions imposed by retail units it was not possible to use what *a priori* was believed to be the optimum design. However, for partial preference analysis, the Latin square design suggests itself as a worthy candidate. On the other hand, partial preference analysis may be invalid in view of the interactions that may result from the simultaneous treatment of several factors (such as size, grade and color). Since the number of treatments under this situation proves to be large, an incomplete block design may be indicated as necessary.

VI. SUMMARY

This study was concerned with estimating the short-run price-consumption relationships for eggs. At the outset, it was noted that any statistical method of estimation derives its meaning and area of applicability from the concept of a well defined sampling model. The restrictive nature of economic data obtained from passive observation suggests in many cases, as a necessary alternative, observations generated from a controlled experiment to reflect the variables specified in the economic model. In this study, a randomized block design in conjunction with a factorial arrangement of treatments was chosen to generate the data for the specified models.

Using experimentally generated data, short-run price-consumption relationships were estimated for all eggs, grade AA, grade A, grade B, and non-graded eggs. Each of the relationships was subjected to an economic interpretation and the uses and implications of the results for decision making were discussed.

VII. APPENDICES

APPENDIX A.—Analysis of variance for price level changes

Source	Degrees of Freedom	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	.83	2.19	
Error	96	802.7424	8.3619			

Standard error of grade mean: 0.56

Grade means:	(AA)	(N.G.)	(B)	(A)
	1.97	3.56	3.69	9.89

APPENDIX B.—Impact of Income on Sales

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

1. All eggs.

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

$$y_1 = 54.66 - 0.5170\, x_1 - 0.0169\, z_7 \qquad \text{(B.1)}$$
$$(0.0544) \qquad (0.1759) \qquad R^2 = 0.80$$

where y_1 represents the total consumption of eggs in dozens per 100 customers, z_1 represents the average price of all eggs in cents per dozen, and z_7 represents the average gross store sales per 100 customers.

The magnitude of the coefficient of z_1 coupled with the negative sign and large standard error may lead to a rejection of the hypothesis that average gross store sales can serve as an income variable. Alternatively, these results may indicate that, for a commodity such as eggs, the income effect is so small as to be negligible.

2. 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 B.2 and B.3 respectively.

$$y_3 = 17.68 - 0.1308\, z_4 - 0.0163\, z_7 \qquad \text{(B.2)}$$
$$(0.0222) \qquad (0.1548) \qquad R^2 = 0.70$$
$$y_4 = 12.61 - 0.2384\, z_5 + 0.0241\, z_7 \qquad \text{(B.3)}$$
$$(0.0394) \qquad (0.0506) \qquad R^2 = 0.80,$$

where y_3 represents the consumption of grade AA eggs in dozens per 100 customers, y_4 represents the consumption of grade A eggs in dozens per 100 customers, z_4 represents the price of grade AA eggs in cents per dozen, z_5 represents the price of grade A eggs in cents per dozen and z_7 is defined as in equation B.1.

As in the case of eggs in the aggregate, gross store sales as a measure of income failed to contribute in explaining the consumption of these two grades of eggs. Additional work would seem to be warranted to ascertain the value of gross sales or some other variable as a measure of income.

APPENDIX C.—Analysis of variance (added knowledge)

Source	Degree of Freedom	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
Errors	21	163.5883	7.7899			

Standard error of grade mean: 1.61

Grade means:	(N.G.)	(B)	(AA)	(A)
	2.17	2.94	5.78	14.44

APPENDIX D.—Analysis of Variances for all Treatments

In section IV, 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 D.1. The results of this analysis of variance indicate that treatments attained significance at the 5 percent level while

APPENDIX TABLE D.1—Analysis of variance for all treatments

Source	Degree of Freedom	Sum of Squares	Mean Square	F	F_{05}	F_{01}
Total	314	7195.8645				
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)
3.33	3.61	4.03	4.09	4.09	4.11	4.41	4.62	5.23

grade and grade by treatment interaction attained significance at the 1 percent level.

However, the use of Duncan's Multiple Range test reveals that treatment significance is due to a significant difference between treatments three and nine. 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.

Applying the multiple range test to grade means supplied additional evidence to support the previous analyses and emphasizes the important role of grade A eggs.

2¼M—4-58.