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

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PREFACE

Knowledge relative to short-run price-consumption relationships for beef is a necessary prerequisite for intelligent action by a government or firm. This study reports the use of experimental observations as a basis for estimating these relationships. The study is, to a large extent, methodological in nature, as it presents the results of applying a controlled experiment in estimating consumer response relationships for a particular cut of beef.

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I. INTRODUCTION

Precise economic choice criteria are required by planners at all levels of market activity. In fulfilling this need, the procurement of accurate data from which economic relations may be estimated is of signal importance. Although much of the data used for economic analysis is obtained through the passive observation of reality, controlled experiments may provide a superior alternative since (1) the data may be more nearly representative of the variables specified by the model, (2) greater control over the magnitude of measurement errors may be possible, (3) variables of interest may be varied over ranges sufficient to allow the estimation of important parameters, and (4) the choice of an estimation technique, consistent with the process by which the observations were generated, is simplified.

Within this framework, the major objective of the research reported was to evaluate the effectiveness of a controlled experiment in generating accurate price-response data for the product T-bone steaks.

Under the major objective, several corollary objectives were: (1) to estimate the short-run price-consumption relationships for Choice grade T-bone steak, (2) to estimate the short-run price-consumption relationships for Good grade T-bone steak, (3) to estimate the shortrun price-consumption relationship for the aggregate of these two 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.

II. THE ECONOMIC MODELS AND DATA GENERATION

A. The General Economic Model

The economic models presented represent an attempt to specify short run price-consumption relationships for the commodity T-bone steak. The models are designed to reflect the behavior of consumers when confronted with changing price structures in the market. Economic theory and *a priori* knowledge provide the basis for the specification of the variables and their classifications.

As an aid in considering the economic models to be presented and as a general guide to the specification and classification of variables for a particular problem the following formulation may be useful. Consider the problem where parameter estimates connecting one variable with a set of other variables are desired. In regard to the classification of the variables, the model may be specified as follows:

$$y_1 = f(y_2, y_3, \ldots, y_j, y_{i+1}, y_{i+2}, \ldots, y_j, y_{j+1}, y_{j+2}, \ldots, y_k, y_{k+1}, y_{k+2}, \ldots, y_n; a_1, a_2, \ldots, a_r)$$

where y_1 is a vector of the observed values of the variable whose generation is to be explained; $y_2, y_3, \ldots, y_i$ are vectors of variables whose values will be experimentally controlled over some range; $y_{i+1}\ y_{i+2}, \ldots, y_j$ are vectors of variables that are controlled at a fixed level; $y_{j+1}, y_{j+2}, \ldots, y_k$ are vectors of variables that are observed, but not controlled; $y_{k+1}, y_{k+2},$

. . . , y_n are vectors of variables that are unobserved and uncontrolled; and $a_1, a_2, \ldots, a_r$ are a set of unknown parameters to be estimated.

This general formulation points up the alternative classes of variables that must be considered and makes explicit the process whereby the observations have been or are generated. Within this general framework, several alternative models concerning the reactions of consumers of T-bone steak are specified and the experimental design for generating the data to reflect the variables specified in the model is discussed.

B. Specific Economic Models

For many products, one of the more important economic variables involved in consumer decisions is the price of the product. A model describing the relationship between consumption and price may be postulated as:

$$y_{1t} = f(P_{1t}, z_{1t}, x_{1t}, x_{2t}; a_1, a_2, \ldots, a_r) \qquad (2.1)$$

where y_1 represents the observed quantity disappearance of T-bone steak in pounds per 1,000 customers; P_{1t} represents a set of experimentally controlled prices imposed on T-bone steak in cents per pound; $a_1, a_2, \ldots, a_r$ are parameters to be estimated; z_{1t} represents a set of variables which assume fixed values over the experimental period; x_{1t} represents a set of uncontrolled variables observed over the experimental period; and x_{2t} represents all the unobserved and uncontrolled variables.

Several variants of this model were investigated. In the first variation, y_{1t} represented the total quantity disappearance of T-bone steak; P_{1t} represented the average price of T-bone steak; z_{1t} included such factors as the prices of other cuts of meat; x_{1t} represented such factors as those associated with the location of the store units, the passage of time, and level of total meat sales; and x_{2t} represented all unobserved, uncontrolled variables such as the level of income of store customers and price of commodities other than meat.

A second variation investigated relations where y_{1t} represented the observed quantity disappearance of Choice grade T-bone steaks; P_{1t} represented the set of experimentally controlled prices associated with this grade of steak; z_{1t} represented all the factors included in the ag-

gregate model plus the price of Good grade T-bone steaks; and x_{1t} and x_{2t} represented the factors specified for the aggregate model.

A third variation investigated similar relations for Good grade steak where the variables take on interpretations analogous to those presented for Choice grade steak.

C. Data Generation

The specification of a conditional model requires that the sampling procedures for each of the variables be restricted in a certain manner. The variable P_{1t} is sampled only within designated experimental limits. The variables z_{1t} are sampled only at some fixed arbitrary level or at a level assigned because it is of particular interest. Sampling of the variables x_{1t} and x_{2t} is unrestricted in the sense that they may take on any values that may be generated by the market mechanism during the experimental period.

If it can be assumed that errors in measurement are negligible and that the movements of the variables, x_{2t}, are random in nature, then the variability in y_{1t} arises as a result of changes in the variables P_{1t} and x_{1t}. In order to obtain valid estimates of the parameters of the relationships postulated, some process is needed whereby some type of control is exercised over the variables x_{1t}. In this study, the factors associated with the location of the retail store units and factors associated with the passage of time comprised the set, x_{1t}.

The above considerations led to the postulation of the following statistical model to be used in the generation of the data:

$$y_{ijk} = \mu + d_i + s_j + p_k + e_{ijk} \qquad (2.2)$$

where y_{ijk} represents the quantity disappearance of T-bone steak in pounds per 1,000 customers; μ 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 . . . n; j = 1, 2 . . . n; k = 1, 2 . . . n, this model represents the familiar latin square design. In this research, however, i = 1, 2 . . . 9; j = 1, 2 . . . 8 and k = 1, 2 . . . 9. Model 2.2 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.

III. THE SETTING

A large metropolitan market was desired so that fixed variates, such as income, family size, racial, and religious factors, etc., would include the widest range of values possible. Tulsa, Oklahoma, was chosen as a sampling area that possessed this attribute. This choice also permitted greater administrative control over 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 a single prominent chain of retail outlets were selected within the city. The stores were located in such a manner that the sampling took place throughout the entire city. The stores were further located such that with higher than average price, 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 neighborhood 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 maximum 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.

Consumer buying habits for beef in the Tulsa market have been oriented towards the two federal grades, Choice and Good, and 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 3.1.

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 to price of consumers of Choice grade T-bone steaks. 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.

In order to handle unforseen contingencies and clear up any misunderstanding of the instructions, the following procedure was followed:

TABLE 3.1. 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

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.

IV. THE RESULTS

A. Results for Aggregate T-bone Steaks

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.[1]

1. The Analysis of Variance

The results of the analysis of variance for the aggregate of T-bone steaks are presented in Table 4.1. 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 square for stores.

Included in Table 4.1 is a multiple range test[2] for treatments at the

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

[2] The multiple range test is interpreted as follows: No significant difference exists among any set of underscored treatment means. Thus t_4 is not significantly different from t_7 but is significantly different from all other treatments. Likewise, t_3 is not significantly different from t_8, but is significantly different from all other treatments. None of the treatments arrayed in the table between treatments 4 and 3 are significantly different from one another. For a discussion of the assumptions and computational methods see: Duncan, D. B., "Multiple Range and Multiple F Tests," *Biometrics*, March, 1955.

TABLE 4.1. Analysis of variance for aggregate T-bone steaks.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F	$F_{.01}$
Total	67	20,184.566			
Stores	7	6,059.863	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

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.

2. 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 firms total revenue. One of the simplest formulations postulates a relationship between quantity purchased and average price that is linear in logarithms. The quantified results of such a formulation, using all nine treatments, are presented in Equation 4.1.

$$Q = 5.61 - \underset{(0.30)}{2.09}\ P \qquad r^2 = 0.87 \qquad (4.1)^3$$

where Q 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

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

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 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 4.2.

$$\underset{\substack{\\ \\ (1.02)\quad (1.09)}}{Q = 2.38 - 2.23\ P + 1.11\ I} \qquad r^2 = 0.90 \qquad (4.2)$$

where I represents the logarithm of meat sales in dollars per 1,000 customers and all other variables have been defined previously. This relationship leads to a slightly greater estimate of retail price elasticity than was obtained from Equation 4.1. The sign of the meat sales coefficient is consistent with logical expectation, although the inclusion of the variable added only 3 percent to the total explanation of variation in Q. This may be due to the fact that T-bone sales represent only a small portion of total meat sales.

B. Results for Choice Grade T-Bone Steaks

When a product can be subclassified according to some grading standards, it may be desirable, for certain economic considerations, to possess knowledge concerning the effects of price on each grade.

1. 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 to Table 4.2.

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.

The multiple range test for Choice grade T-bone steaks is not as easy to interpret 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.

2. 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 4.3 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 4.4 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 4.5 presents a relationship covering the 115-75

TABLE 4.2. Analysis of variance for choice grade T-bone steaks.

Source of Variation	Degrees of Freedom	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	2,666.945	233.368	4.77	2.94
Error	44	3,075.818	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

cent price range for Choice when Good was priced at 75 cents per pound (Treatments 9, 6, and 3).

$$Q_c = 6.11 - \underset{(1.33)}{2.45}\ P_c \qquad r^2 = 0.77 \qquad (4.3)$$

$$Q_c = 4.77 - \underset{(0.27)}{1.81}\ P_c \qquad r^2 = 0.98 \qquad (4.4)$$

$$Q_c = 5.80 - \underset{(0.96)}{2.37}\ P_c \qquad r^2 = 0.86 \qquad (4.5)$$

where Q_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 1) of these relationships, converted from the logarithmic form to the original price and quantity units, provides some 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 4.6.

$$Q_c = 4.99 - \underset{(0.39)}{1.93}\ P_c \qquad r^2 = 0.78 \qquad (4.6)$$

where all variables have been defined previously. This relationship provides an estimate of price elasticity of —1.93. 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 4.7.

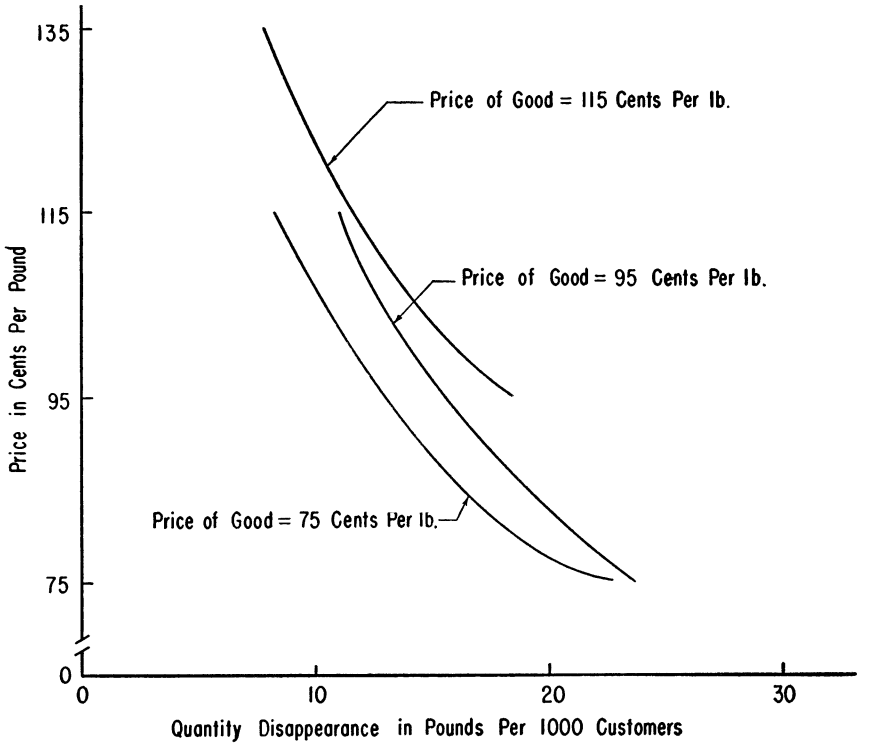

FIGURE 1. Price-consumption relationships for choice grade T-bone steaks at varying prices for good grade T-bone steaks.

$$Q_c = 4.10 - \underset{(0.37)}{2.19}\ P_c + \underset{(0.40)}{0.72}\ P_g \qquad r^2 = 0.86 \qquad (4.7)$$

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 previously. Equation 4.7 indicates a price elasticity of —2.19. The positive sign associated with the coefficient of the price of Good grade steaks supports the hypothesis that these two grades of steak are substitute goods. However, this latter coefficient failed to meet the test of significance at the 5 percent level.

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. To utilize information from this additional variable, 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 4.8.

$$\underset{}{Q_c} = \underset{}{4.19} - \underset{(0.45)}{2.19\ P_c} + \underset{(0.44)}{0.72\ P_g} - \underset{(1.63)}{0.03\ I} \quad r^2 = 0.86 \quad (4.8)$$

where all variables have been defined previously. 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 independent cardinal measure of expenditures on T-bone steak was available, an attempt to eliminate these effects 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 4.9.

$$\underset{}{Q_c} = \underset{}{0.45} - \underset{(0.28)}{0.86\ P_c} + \underset{(0.16)}{1.21\ P_g} \quad r^2 = 0.97 \quad (4.9)$$

where all variables have been defined previously.

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 4.9 indicates the price of Good grade steaks is an impotrant 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 2.

C. 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.

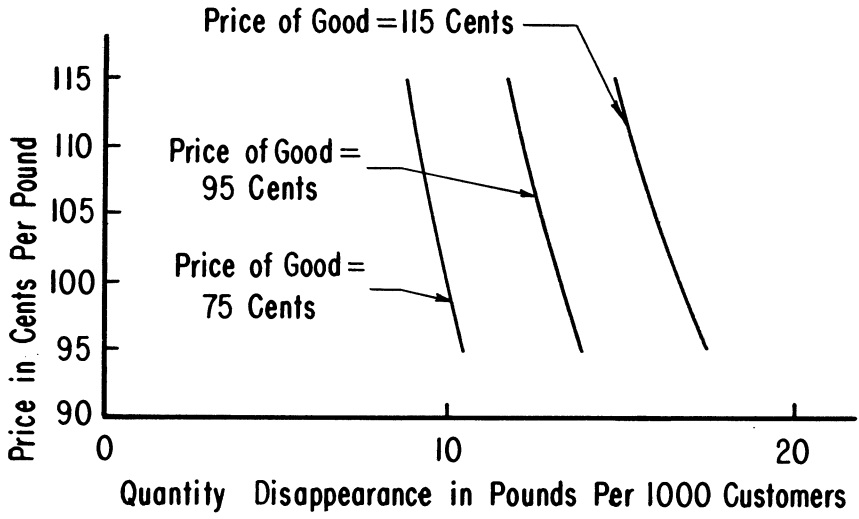

FIGURE 2. Price-response relationships for choice grade T-bone steaks at a fixed expenditure level.

1. The Analysis of Variance

The results of the analysis of variance for Good grade T-bone steaks are presented in Table 4.3. From the information in Table 4.3, 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.

TABLE 4.3. Analysis of variance for good grade T-bone steaks.

Source of Variation	Degrees of Freedom	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

Results from the multiple range test indicate that sales of Good grade T-bone steaks decreased significantly from 95 to 115 cents per pound when Choice was priced at 115 cents per pound. However, when Choice grade T-bone steaks were priced at 95 cents per pound, 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.

2. 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 4.10 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 4.11 presents a similar relationship when Choice grade steaks were priced at 95 cents per pound (Treatments 2, 6, and 7).

$$Q_g = 3.96 - \underset{(0.04)}{1.42}\ P_g \qquad r^2 = 0.999 \qquad (4.10)$$

$$Q_g = 10.02 - \underset{(1.12)}{4.58}\ P_g \qquad r^2 = 0.94 \qquad (4.11)$$

where Q_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 previously.

The relationship presented in Equation 4.10 provides a near perfect statistical fit and yields 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 4.12 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 were not constant for all treatments involved in this relationship, the magnitude of the resulting parameter is overestimated. This fact is particlarly evident in a graphical representation of the two equations (Figure 3) converted from the logarithmic form to the original price and quantity units.

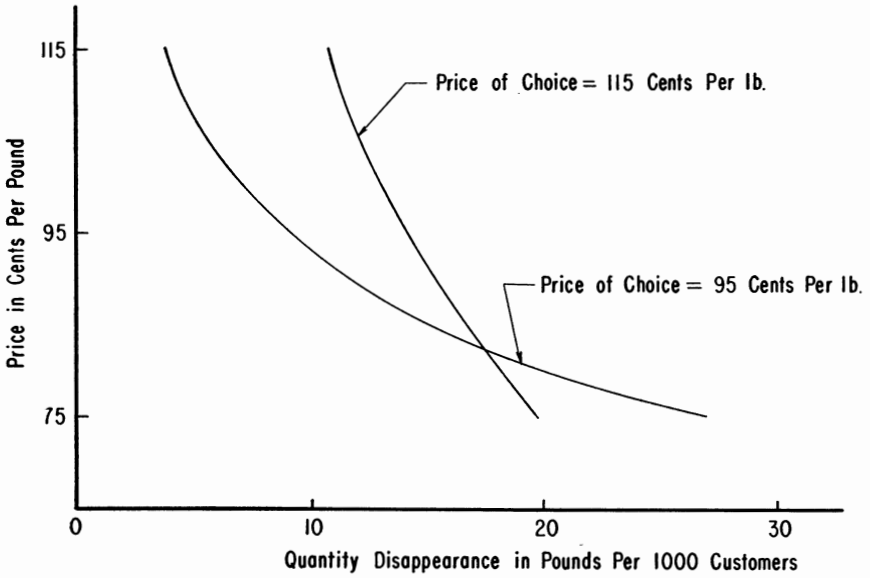

FIGURE 3. Price-consumption relationships for good grade T-bone steaks at varying prices for choice grade T-bone steaks.

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, the price of Choice grade steak, and the average value of meat sales. Quantifying such a model resulted in the estimates presented in Equation 4.12.

$$Q_g = -2.33 \underset{(0.81)}{-3.00}\ P_g \underset{(0.82)}{-0.09}\ P_c + \underset{(3.00)}{3.02}\ I \qquad r^2=0.76 \quad (4.12)$$

where all variables have been defined previously.

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 4.13.

$$Q_g = 4.75 - \underset{(0.76)}{0.06}\ P_c - \underset{(0.44)}{1.76}\ P_g \qquad r^2 = 0.90 \qquad (4.13)$$

where all variables have been defined previously. From this relationship the price elasticity of Good grade T-bone steaks is estimated as —1.76. In this relationship, as in Equation 4.12, 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 4.13 are presented graphically in Figure 4.

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

Considerable interest has risen with respect to the question of consumer preferences among alternative grades of meat.[4] 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 4.4 indicate that extreme caution should be exercised in evaluat-

TABLE 4.4. 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

[4] Branson, R. E., *The Consumer Market for Beef,* Texas Agricultural Experiment Station Bulletin 856, April, 1957.
Rhodes, V. J., Kiehl, E. R. and Brady, D. E., *Visual Preferences for Grades of Retail Beef Cuts,* Missouri Agricultural Experiment Station Bulletin 583, June, 1955.
Seltzer, R. E., *Consumer Preferences for Beef,* Arizona Agricultural Experiment Station Bulletin 267, October, 1955.

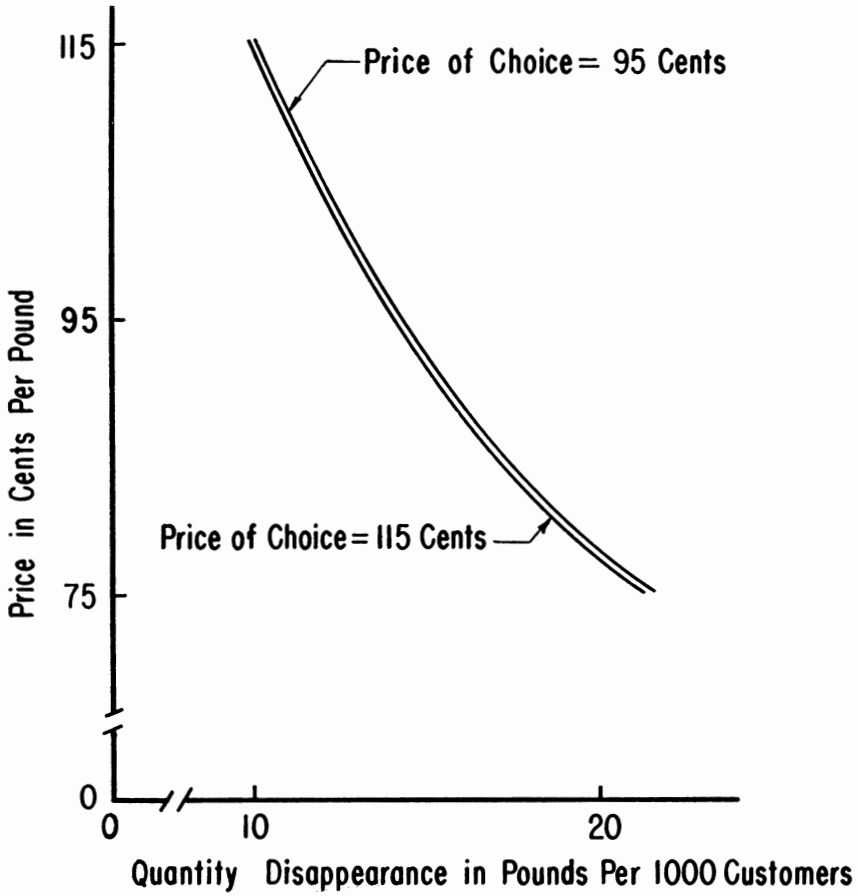

FIGURE 4. Price-response relationships for good grade T-bone steaks at a fixed expenditure level.

ing consumer preferences based on a single price level.

The sample data presented in Table 4.4 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. A possible explanation of

these results may be that as the price level of T-bone steaks decreases, many persons preferring the Good grade of steak are no longer priced out of the market.

Alternatively, the data of Table 4.4 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 5 and have been converted from the logarithmic form to relationships in the original units. These relationships demonstrate perhaps more clearly 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.

1. 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 4.14. The data

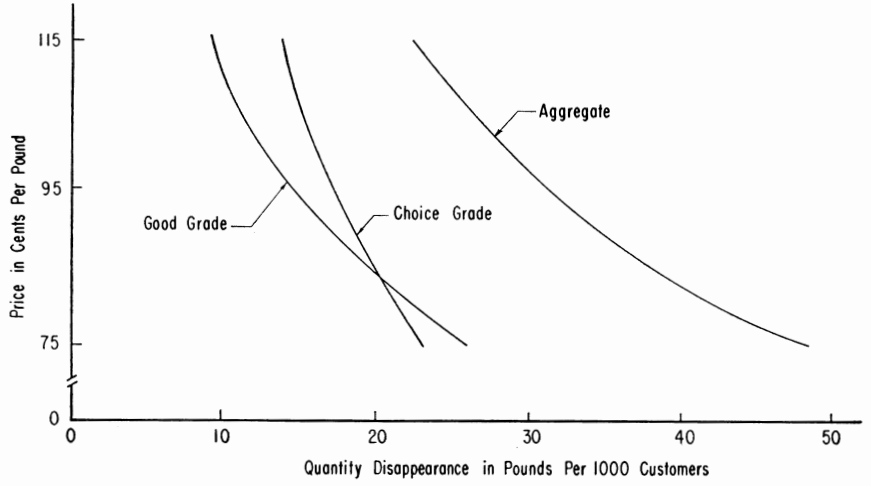

FIGURE 5. Price-consumption relationships for T-bone steaks by grades and for aggregate under three price level treatments.

for this relation was generated by Treatments 1, 2, and 3.

$$Q = 5.06 - 1.80\ P \qquad r^2 = 0.87 \qquad (4.14)$$
$$(0.70)$$

where all variables have been defined previously. 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 represents an estimate of the retail price elasticity. For comparative purposes, an equation was estimated which excluded Treatment 4.[5] The results are presented in Equation 4.15.

$$Q = 5.44 - 2.00\ P \qquad r^2 = 0.81 \qquad (4.15)$$
$$(0.39)$$

where all variables have been defined previously. It is apparent from Equations 4.14 and 4.15 that the estimate of elasticity under price level changes is not appreciably different from the estimate of elasticity under the alternative pricing scheme.

2. 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 4.16 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.

$$Q_c = 3.67 - 1.23\ P_c \qquad r^2 = 0.76 \qquad (4.16)$$
$$(0.68)$$

where all variables have been defined previously.

This relationship does not have the same economic meaning as the previous relationships since the price of the competing grade was not

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

held constant. In addition, this equation suffers somewhat to the extent of the shift in T-bone expenditures. If adjustments could be made to compensate for the shifts in expenditures, the magnitude of the price coefficient could be expected to be somewhat larger.

3. 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 4.17.

$$Q_g = 6.01 - \underset{(0.69)}{2.45}\ P_g \qquad r^2 = 0.93 \qquad (4.17)$$

where all variables have been defined previously.

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 Good grade steaks are considerably more price elastic.

V. IMPLICATIONS OF THE RESULTS

The implications to be drawn from the results presented in the previous section fall into two categories. The first of these comprises the implications surrounding the methodological approach to the problem of data generation. The second comprises the implications pertaining to the use, by retail marketing firms, of the parameter estimates obtained from this type of data. In view of the scope of this study, the estimated relationships are valid only under an extremely restrictive set of circumstances. However, given a sound methodology and the resources to employ it, such a limitation can be reduced through a sequential analysis where the *ceterus paribus* restrictions on certain variables of the static model are relaxed.

A. Methodological Implications

The results of this research contain methodological implications. The first aspect of the estimation process concerns the problems associated with model construction. Choices must be made with respect to the variables to be included or excluded from the model and such choices are conditioned to a large extent by the availability of suitable data.

Although vast quantities of data are available, much of it is not generated or collected primarily for economic analysis. Consequently, it may fail to meet the requirements of the theoretical model. In addition, some important variables are measurable only in an ordinal sense, making inclusion in a quantitative model difficult.

The results of this study imply that it is possible to reduce measurement errors to insignificant proportions. This fact in turn serves to point up the magnitude of specification errors and the consequences on the predictive ability of a given model. Controlled experiments may, therefore, provide economists with a valuable means of investigating such errors associated with demand relations. A few well designed experiments might lead to improved sector models with a more efficient use of research resources.

The results of the research reported here accent the importance of ordinally measurable variables as a source of specification bias. The experimental methodology may provide a means of including important ordinally measurable variables in a given model through proper classification of the ordinal variates and subsequent adjustment of the appropriate cardinal variates.

Although it may be impossible, with a finite number of observations, to obtain a unique estimate of a theoretical indifference curve, it may be possible to obtain a range in which the true indifference curve lies. However, until some means of obtaining an independent measure of income is devised, the possibility of such estimates will remain rather remote.

With respect to data procurement, the results of this research imply that the experimental technique provides a means of generating data with accuracy sufficient for economic analysis. Equally as important is the fact that the variables measured can be representative of the

variables of the theoretical model. In view of the limited amount of data that can be obtained in a given experiment, it appears that controlled experiments can be used to the greatest advantage in procuring data for the testing of basic economic models. When specification errors have been reduced to insignificant proportions, other methods may provide data with sufficient accuracy to permit intelligent decisions. Underlying all of the above is the fact that if the information provided by economic models is valuable to society, then there is a continuing need for additional coordinated efforts among firms, consumers, data collecting agencies, and economists to provide the necessary data.

Lastly, the results indicate that the level of price has an impact on the relative consumption pattern for T-bone steaks. This implies that researchers should consider modifying the current techniques being used to estimate consumer preferences for alternative grades of products.

B. Implications for the Firm

It is re-emphasized that, due to the restrictions imposed by the static model, the particular results of this study do not have widespread application. However, certain inferences may be warranted for the limited sector studied. For example, assume that a retail firm finds it expedient to sell 25 pounds of T-bone steaks per 1,000 customers in order to adjust inventories. Employing the relationship presented in Equation 4.1, T-bone steaks should be sold for $1.04 per pound.

Alternatively, another problem that might be analyzed is the following: If the price of Good grade steaks is to be set at 79 cents per pound and the firm wishes to sell 10 pounds of Choice grade steaks per 1,000 customers, what price should be charged? Employing the relationship presented in Equation 4.11, the price of Choice grade steaks is computed to be $1.07 per pound.

The type of relationships presented in the results section might also be used to solve purchasing problems of the firm, i.e., given a set of retail prices for T-bone steaks, what supplies will need to be purchased in order to meet the demand? Or alternatively, given certain supply costs of T-bone steaks, what price should be charged in order to maximize expected profits?

The simple analysis presented above has failed to take into consideration the many other cuts comprising a beef carcass. A firm, in setting its prices on T-bone steaks, would, of course, need to consider the effects on the other beef cuts as well as the effects on other types of meats. Such considerations point up the need for additional research along such lines.

VI. SUMMARY

This research was concerned with an investigation of the effectiveness of a controlled experiment in generating data representative of the theoretical economic variables and with accuracy such that the relationships estimated provide a sound basis for firm policy.

To accomplish this end, a simple, static economic model was constructed and reformulated in terms of an appropriate statistical design—in this case, an incomplete Latin square. The data generated through the employment of this design was used to estimate price-response relationships for Choice and Good grade T-bone steaks as well as the aggregate of both grades. Each of the relationships was subjected to statistical tests and an economic interpretation.

In particular, in the range of \$0.95 to \$1.15 per pound, the price elasticity for Choice grade T-bone steak was estimated at —0.86. In the range of \$0.75 to \$1.15 per pound the price elasticity for Good grade T-bone steak was estimated at —1.76. Over a range of \$0.75 to \$1.25 per pound the price elasticity for the aggregate of these two grades was estimated at —2.23. Investigation of the effects of price level changes provided some evidence that at higher price levels, total sales would be comprised predominantly of purchasers of the Choice grade steak.

Implications of the methodology of controlled experiments in this area of marketing research are discussed as well as the implications concerning the possible uses of the estimated relationships for policy decisions by retail firms.

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