THE IRREVERSIBLE DEMAND FUNCTION FOR BEEF

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THE IRREVERSIBLE DEMAND FUNCTION FOR BEEF

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PREFACE

Demand analysis is one aspect of investigating consumer behavior. This study examines consumer behavior with respect to the demand for beef and its particular characteristics during the two phases of the beef cycle. Consumer behavior in the two phases is compared with regard to their response to price and income changes. It is hypothesized that consumer response to price and income changes in the increasing price phase of the beef cycle is different than during the decreasing price phase. This behavior is assumed to be caused by the cyclical nature of beef production and the formation of habits of increasing beef consumption during the decreasing price phase. This hypothesis is empirically tested and the results indicate that the long run demand function for beef at the retail and wholesale levels, should be visualized as an irreversible function.

I am greatly indebted to my major adviser Dr. J. W. Goodwin for his counsel and supervision throughout the period of my graduate program and the writing of this thesis. Sincere appreciation is extended to Dr. J. E. Martin for his assistance in the statistical analysis and constructive criticisms during the preparation of this study.

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I would like to acknowledge the invaluable assistance of the Statistical Section of the Department of Agricultural Economics under the direction of Miss Pat Cundiff in much of the computational work.

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CHAPTER I

INTRODUCTION

The idea of irreversibility of economic reactions is one of the most interesting aspects of economic behavior. Irreversibility of the demand function can be classified as one component of this general concept. The concept of irreversibility in the demand relation is not new. However, it has been investigated empirically only with respect to a few specific problems. Marshall[1], Mighell and Allen[2], Ferger[3], Brown[4], Farrell[5], and Koyck[6] have implicitly and explicitly raised this problem and suggested various causes that might be responsible for the phenomenon. Most of the authors conclude that consumption habits are the major factor causing this type of reaction.

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[1]Alfred Marshall, Principles of Economics (New York, 1948), eighth edition, p. 807.

[2]R. L. Mighell and R. H. Allen, "Demand Curves-'Normal' and 'Instantaneous'," Journal of Farm Economics, XXI (1939), pp. 555-569.

[3]Wirth F. Ferger, "The Static and Dynamic in Statistical Demand Curves," The Quarterly Journal of Economics, XLVII (1932-33), pp. 36-62.

[4]T. M. Brown, "Habit Persistence and Lags in Consumer Behavior," Econometrica, XX (1952), pp. 355-371.

[5]M. J. Farrell, "Irreversible Demand Functions," Econometrica, XX (1952), pp. 171-186.

[6]L. M. Koyck, Distributed Lags and Investment Analysis (Amsterdam, 1954), pp. 1-39.

The concept of "irreversibility" describes a situation in which consumers exhibit a certain pattern of behavior under a certain set of conditions which prevails for some period of time, and then later change this pattern as a result of changing circumstances. When these consumers are again confronted with conditions similar to those they faced originally, their behavior is different from the behavior they exhibited during the initial period. An example may serve to clarify this idea. A consumer with an income of $4,000.00 per year will form a certain pattern of behavior of spending perhaps $3,000.00 on consumption. If his income rises to $5,000.00 per year, and remains at this level for a period of time long enough for him to adjust his consumption expenditure pattern, he will now behave differently and spend, say $4,000.00 on consumption. If afterwards his income should return to $4,000.00, rather than his consumption expenditure being reduced to $3,000.00, it would stay at some higher level of perhaps $3,500.00. Thus, his reaction is irreversible--that is, he does not return to the original point.

Observations of time series data for prices and consumption in the beef sector suggest the existence of irreversibility in the demand for beef. This may be seen in Figure 1 which shows the per capita consumption and retail prices for beef during the period 1947-1965. A similar response pattern can be recognized at the wholesale and farm levels (see Appendixes A and B).

The possible existence of an irreversible type of demand function for beef might be explained by the existence of consumption habits and the cyclical pattern of prices and consumption. Figure 2 shows the cyclical patterns of per capita consumption and retail beef prices for the period 1947-1965. In this figure, three periods of decreasing

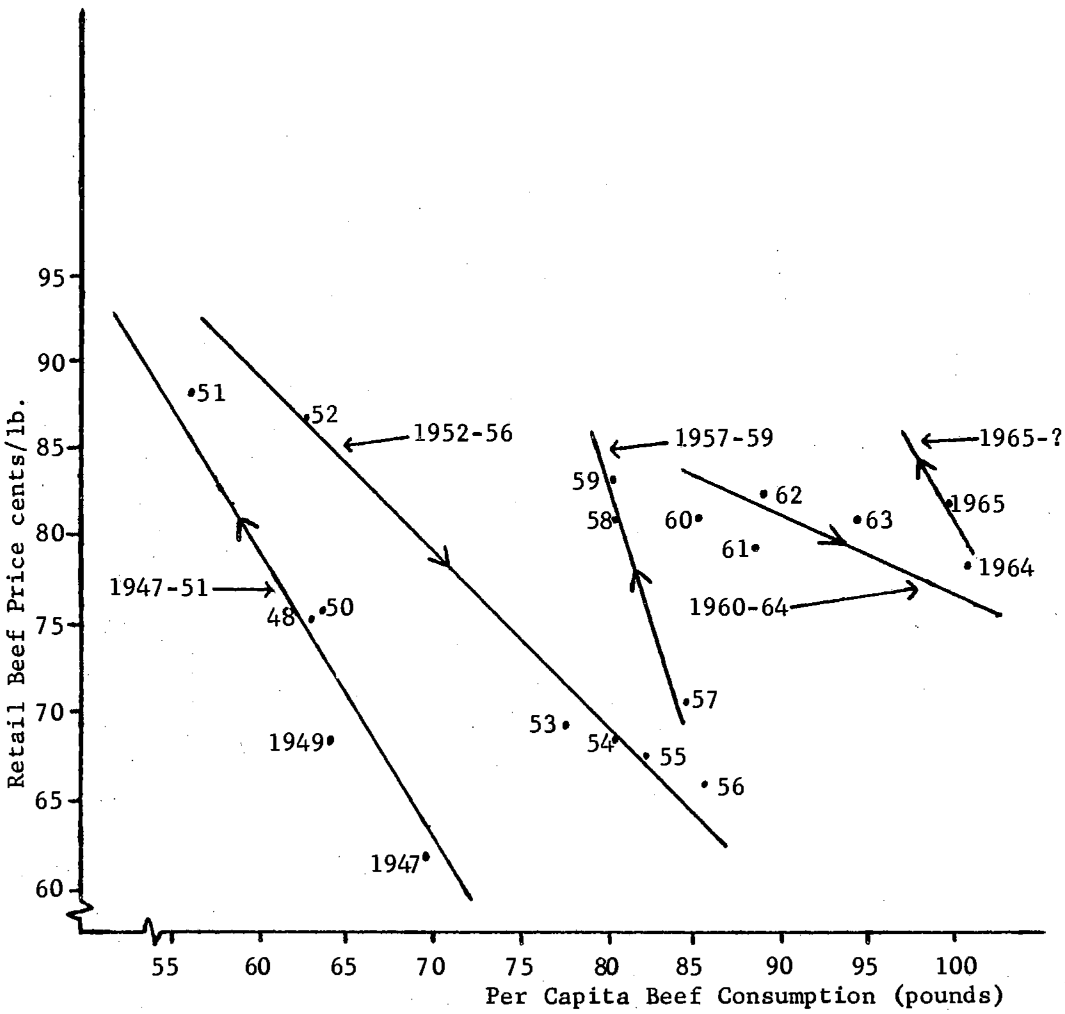

Figure 1. "Consumption Response" for Beef at the Retail Level.
Retail Price and Per Capita Consumption 1947-1965

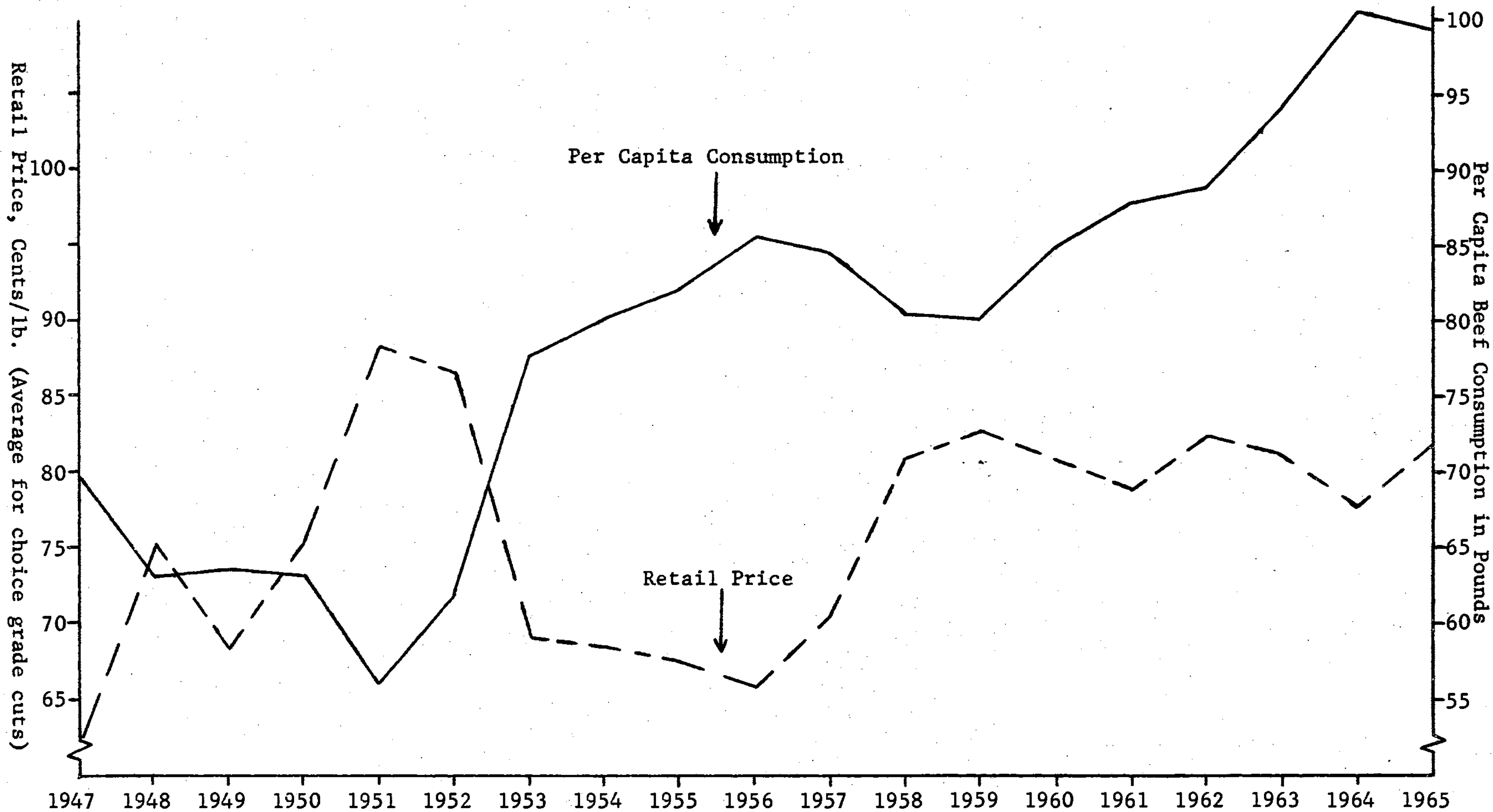

Figure 2. Cyclical Patterns of Beef Price at Retail and Per Capita Beef Consumption 1947-1965.

consumption and two periods of increasing consumption can be observed. The price cycle generally follows a pattern opposite to that observed in the consumption cycle--when prices are decreasing consumption is increasing and *vice versa*.

The problem with which this study is concerned is whether consumer behavior in a period of cyclically increasing price is different from that behavior in periods of cyclically decreasing price. The general hypothesis examined in this study is that during a period of decreasing beef prices (holding real income constant) consumers increase the quantity demanded. They become accustomed to consuming more beef and to substituting it for other meat products, thus forming a habit of consuming an increased amount of beef per unit of time. Persistence of this habit during a subsequent period during which prices increase slows down the reaction of reduced consumption. This implies that during the increasing price phase consumers are willing to buy more beef at a given price than they purchased during the declining price phase. Further, it is hypothesized that consumer adjustment to changes in prices and/or income is of one type during phases of decreasing price, and of a different type during phases of increasing price.

The objectives of this study are to define and explain some of the factors that may cause the irreversible nature of consumer behavior with regard to beef consumption. Further objectives are to measure the magnitude of any effect that may result from these causal factors, and to suggest some implications that might improve the prediction of consumer behavior under particular conditions.

The importance of consumption habits in consumer demand analysis is explained stressing the point that the irreversibility phenomenon is associated with a long-run, dynamic demand function. A concept of "consumption response" which describes the general phenomenon of irreversible demand relations is developed, and its applicability to the demand for beef is shown. The hypothesis of an irreversible demand function for beef, and different types of consumer adjustment during the two phases of the beef cycle is tested at the retail, wholesale and farm levels. A distributed lag model with two lag parameters is applied and enables the estimation of consumer adjustment to price and income changes during the two phases of the beef cycle. Own price elasticities and income elasticities are computed for each period, as well as "response" elasticities for the general case of increasing and decreasing consumption phases. The response elasticities are computed under assumed equilibrium conditions in order to compare consumer behavior during the two phases of the beef cycle.

CHAPTER II

THEORETICAL CONSIDERATIONS

The importance of habits as determinants of consumer demand have long been recognized in the literature. Habit is often mentioned with respect to consumer reaction to changes in prices and incomes. Marshall alluded to the existence of irreversible reactions when he recognized the limitations of the static concept of demand.

> It must however be admitted that this theory is out of touch with real conditions of life, in so far as it assumes that, if the normal production of a commodity increases and afterwards again diminishes to its old amount, the demand price and supply price will return to their old positions for that amount.
>
> Whether a commodity conforms to the law of diminishing or increasing returns, the increase in consumption arising from a fall in price is gradual: and, further, habits which have once grown up around the use of a commodity while its price is low, are not quickly abandoned when its price rises again. If, therefore, after the supply has gradually increased, some of the sources from which it is derived should be closed, or any other cause should occur to make the commodity scarce, many consumers will be reluctant to depart from their wonted ways.[1]

In analyzing the effects of habit on consumer behavior, two major problems arise with respect to the terms used in the analysis. First, what is the conceptual difference between "tastes and preferences" and "habits"--two terms which are often used interchangeably. Secondly, how long is the time period with which we are concerned, and in economic

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[1]Marshall, p. 807.

terminology, is it a short run or a long run?

Tastes and preferences are recognized as determinants of consumer demand. The idea of maximizing consumer satisfaction which underlies the entire concept of demand is related to these determinants. The traditional analysis used in constructing indifference curves requires that the consumer be able to state his preference among all possible combinations of commodities. The alternative revealed preference approach developed by Samuelson[2] does not require that the consumer state his preference, but utilizes the consumer's market behavior--the quantities purchased at various prices--in the construction of indifference curves. The central notion of the revealed preference theory is that it is possible to draw a straight line budget equation through any observed point of equilibrium. All combinations of goods on or within the budget line could have been bought in preference to what was actually bought. But, the fact that some specific combination A was purchased rather than combination B or combination C--which are no more expensive --indicates that A was revealed to be prefered to B and C. Both of these approaches define an indifference curve as reflecting a given state of tastes and preferences. In the real world, and particularly in the long run, tastes and preferences are not constant. Various forces such as new products, changing technology, and fashion cause tastes and preferences to change over time. The indifference curve therefore describes a static situation, whereas by relaxing the assumption of constant tastes and preferences a dynamic dimension is introduced into the demand function. In this study the condition of constant tastes and

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[2]Paul A. Samuelson, "Consumption Theory in Terms of Revealed Preference," Economica, XV (1948), pp. 243-251.

preferences is relaxed, and it is hypothesized that forming and breaking habits are major factors in determining the demand relation for beef. Norris states:

> By assumption he [the consumer] has certain rather rigid habits--he consumes, let us say, potatoes as a main staple of his diet and uses a certain amount of safety pins, Lucky Strikes, a certain amount of Ivory soap and Heinz's catsup per month.[3]

It appears logical to assume that a consumption habit is attached to any commodity which is consumed regularly. The question is how long does it take to form a habit and what factors determine the "stickiness" of this habit. The answer is, of course, different for any commodity and would in general depend on the rank of the commodity in the consumer's preference hierarchy, his tastes, the price of the commodity, the consumer's income, and the availability of close substitutes. Thus, habits are not necessarily personal "likes" and "dislikes" for specific items. What a consumer "likes" or "dislikes" is reflected by his set of tastes and preferences. Habits are reflected by what he is accustomed to consuming, and thus describe in a major way the relationship between taste and preference and the economic environment of income and prices.

Tomek and Cochrane define "habit" as follows:

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[3]Ruby T. Norris, The Theory of Consumer's Demand (New Haven, 1941), p. 100.

> Habits impede quantity adjustments to a price change. They are formed patterns of behavior which can be changed or broken. However, a 'cost' is involved in changing this pattern of behavior. Thus, habits affect the rate of quantity adjustment to price change.[4]

It can thus be suggested that it is appropriate to distinguish between tastes and preferences which are structural parameters in the demand relation and habits which affect the rate of quantity adjustment to price and/or income change.

The second problem, namely, the question of time and length of run involved in the analysis of habits and their effects can now be examined. It is obvious that time is required to induce a consumer to break existing habits or to adopt new ones as a result of changes in income or prices. Norris states:

> If tastes and incomes be considered the two major variables behind consumer demand, then the 'short-run' for purposes of an analysis of demand can be defined: a period of time so short that no changes in income occur and no changes in established consumption rates occur. The 'long-run' would then be a period during which habits are formed and broken, and income may increase or decrease.[5]

From these definitions it is obvious that the formation of habits are most properly related to the long run demand function. A second approach which leads to a similar conclusion is the traditional approach which simply states that time is required for a complete quantity adjustment to a price or income change. Since both prices and incomes are

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[4]William G. Tomek and Willard W. Cochrane, "Long-Run Demand: A Concept and Elasticity Estimates for Meats," Journal of Farm Economics, XLIV (1962), p. 719.

[5]Norris, pp. 97-98.

constantly changing, a complete adjustment in the real world is never reached and of course cannot be observed. It is impossible to observe the long run equilibrium because during the period of adjustment, new factors that disturb the movement toward long run equilibrium occur. What is actually observed is merely a series of short run equilibria. Tomek and Cochrane[6] hypothesize that the adjustment period for most food items is one year or less. The fact that most food products are purchased several times a week, and that food prices are frequently advertized reduces the degree of imperfection in the food market. Tomek and Cochrane tested the above hypothesis with respect to beef and pork and concluded that complete quantity adjustment to a price change takes place within one year. This implies that monthly or quarterly observations should be used for estimating adjustment periods for most food products. Martin[7] also suggests that consumers may adjust their consumption of frequently purchased food items fairly rapidly when prices change. This study is concerned with consumer reaction during the two phases of the beef price cycle. Both phases of the cycle are several years in length, and it may therefore be assumed that habits might be formed or broken during any given phase. Thus, based on Norris's definitions, and on the findings of Tomek and Cochrane and Martin, it is apparent that the demand function of interest is the long-run function.

It is also important in this analysis to distinguish between the "static" and "dynamic" demand theories. The above definitions of long

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[6]Tomek and Cochrane, pp. 717-730.

[7]James E. Martin, "Isolation of Lagged Economic Responses," To be published in The Journal of Farm Economics, February 1967.

and short run as stated by Norris are the same as the definitions for static and dynamic, and they require that in the long run some factor will cause a change in existing habits. Ferger[8] points out that changes can occur only over a period of time, but it must be remembered that time may pass without being accompanied by a change in the phenomenon under scrutiny. Thus, the essense of the dynamic is change and not merely the passage of time. Gilboy[9] uses the term "dynamic" in the sense of any change over time. It may be regular and predictable variation or it may be an irregular change which completely rearranges the original parameters of the variables. She also argues that the term "elasticity" as ordinarily used by economists is inevitably tied to a static assumption and cannot be applied to a dynamic curve which is considered as a path of points of equilibria. Mighell and Allen[10] approach the problem of consumer response over a longer than short run period. They argue that changes in consumer habit are not necessarily reversible, and propose consequently that the long run demand curve should be visualized as an irreversible curve applying to a particular period of time. Each point on this curve represents the result of a different price level during the appropriate preceding period.

To this point the analysis has treated the questions of habits and the relevant time concept separately. It is now necessary to combine these two aspects in order to examine the importance of habits in demand analysis. The Marshallian demand curve related changes in quantity

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[8]Ferger, pp. 44-45.

[9]Elizabeth Gilboy, "Demand Curves in Theory and Practice," The Quarterly Journal of Economics, XLIV (1929-30), p. 617.

[10]Mighell and Allen, p. 563.

demanded to changes in price, ceteris paribus. Under the ceteris paribus assumptions, if a change in price induced a change in quantity of a certain magnitude, the return of price to its original position will result in exactly the same quantity change in the reverse direction. This implies that the demand curve is reversible. The conventional concept of price elasticity applies only under these static conditions.[11] Obviously the main interest in this study is a long run dynamic demand function, and the elasticity estimates derived cannot be interpreted in the conventional static sense.

The development of distributed lag theory furnishes a powerful tool for analyzing problems of dynamics in demand analyses. Koyck[12] and Nerlov[13] list several reasons for the reactions of consumers being spread over a certain period of time. These are institutional, technological and subjective in nature. In analysis of demand for food commodities, the subjective reasons seem to be most important in explaining lagged reactions. These are imperfect knowledge of the market and psychological inertia of the consumer. The latter term refers to the consumer's reluctance to make instantaneous adjustment because of uncertainty about future prices and income, and because of consumption habits. Also, consumers might not consider a relatively small change in prices or income as justification for re-evaluating their entire consumption patterns. Thus, they may not adjust consumption immediately to every

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[11]Gilboy, p. 617.

[12]Koyck, pp. 6-9.

[13]Marc Nerlov, "Distributed Lags and Demand Analysis for Agricultural and Other Commodities," Agriculture Handbook No. 141 (1958), pp. 5-7.

price or income change. Tomek and Cochrane hypothesize that of the above impediments, consumer habit may be the most important in creating lagged quantity response to price change.

A major problem in empirical studies of this nature is that a researcher must deal with qualitative variables. Habit cannot be measured directly. Instead, the type of adjustment which is assumed to be caused by the habitual behavior is estimated. Thus, this study compares consumer behavior with regard to the demand for beef during the two phases of the beef cycle.

Katona's approach tends toward a "behavioristic" analysis of consumer behavior. He states that the relevant question to be answered by empirical investigations is "When, under what circumstances is one kind of consumer behavior likely to occur, and when, under what circumstances another kind of behavior?"[14] His findings show that in most instances consumers follow habitual patterns without making decisions. For purchases of less than $100, planning and decision making are infrequent. Most food expenditures will fall in this category. Katona also argues that in general the smaller the single expenditure and the more frequently it is made, the more likely it is to take the form of a habitual expenditure.

Analysing consumer behavior during two periods in which the circumstances were different, Brown[15] used an approach similar to that suggested by Katona. He was concerned with the impact of the habitual behavior

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[14]George Katona, Psychological Analysis of Economic Behavior (New York, 1951), p. 64.

[15]Brown, pp. 355-371.

in one period upon the consumption in the following period. In a study of the effects of habits on the aggregate consumption function, Brown used a shift variable of the "zero-one" type to describe shifts in demand in the post-war period compared with the pre-war period. This "zero-one" variable may be interpreted as the aggregate impact of all the non-measurable variables such as consumer habit, the psychological impact of price controls, and the introduction of new products and new technology. A war causes changes in prices and incomes and can be explained as a disturbance factor in the consumers' habitual behavior. These changes cause consumers to break existing habits and form new ones. Brown hypothesizes that consumption habits associated with the level of real consumption previously enjoyed become "impressed" on the human psychological system and this produces an inertia or "hysteresis" in consumer behavior. Past consumption exerts a stabilizing effect on current consumption, and this habit persistence causes the adjustment to current changes in price and income to be lagged. This effect dissipates gradually through time. Brown tested two hypotheses. First, he hypothesized that the time lag was discontinuous; in this case it was assumed that the habit persistence effect was produced by the highest previous level of real consumption experienced. The second hypothesis was that the effect of past habits is continuous over time. The approach to habit formation was that past real consumption patterns and levels form habits which persist long enough to reduce the effects of current income on current consumption. The second hypothesis produced the best results, conforming with both economic rationale and statistical tests for goodness of fit.

Farrell[16] related irreversible demand functions to an explanation of trends in the consumption of coffee, tea, beer, and tobacco in England. People will increase consumption of some commodities more readily than they will curtail it, thus giving a positive trend to the demand for those commodities. He also studied the behavior under pre-war and post-war circumstances and suggested that irreversibility is quite an important factor in the change of tastes that occurs in the general upheaval of a war.

Irreversible relationships can be observed with respect to the aggregate consumption function and some particular commodities. There is a strong basis for believing that the phenomenon of irreversibility is to a considerable degree caused by habit persistence. Further, irreversibility should be related to the long run as it is ordinarily defined with connection to any particular commodity analysed. The situation under analysis is of a dynamic nature. This is emphasized by the argument that some remarkable changes in the determinants of demand or in the external environment must be present in order to induce consumers to change habitual behavior.

The Concept of "Consumption Response"

It is the purpose of this study to test for the existence of a certain type of consumer behavior which can be defined as "consumption response". This concept is based upon the phenomenon of irreversibility and the factors which may cause the demand relation to be irreversible. The meaning of the "consumption response" concept with respect to a

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[16] Farrell, pp. 174-175.

particular commodity can be summarized as follows: During a period in which prices of a product decrease and the quantity demanded increase as a result of some change(s) in the conditions of supply (these conditions persisting over a period of time long enough for consumers to have made complete adjustment), consumers form the habit of consuming the product at a certain rate. In the following period of reverse conditions (also persisting for a long run period) consumers reduce their consumption of the product, but at a rate lower than that at which consumption was expanded. In other words the "response" elasticity in a phase of increasing consumption is greater than in the following phase of declining consumption. This is illustrated graphically in Figure 3.

The concept of "consumption response" is based upon the phenomenon of irreversibility. However, the "consumption response" concept differs in one respect: namely, that it is suggested that the concept may be most properly applied to commodities which show cyclical patterns of production and consumption. In other words, the concept is appliable under intermittent conditions which may be predicted upon the basis of past knowledge with a fair degree of accuracy.

The concept of irreversibility in past empirical studies has used an unpredictable external factor such as war as the basis for the observed irreversibility. This enabled researchers to compare pre-war behavior to post-war behavior and to relate the differences to some cause such as habit. This approach is in fact an *ex post* analysis. The concept of "consumption response" is in this respect an *ex ante* approach, since it enables the researcher to predict a certain type of behavior which can be expected to occur in the future under conditions which presumably will be similar to past circumstances. This approach basically

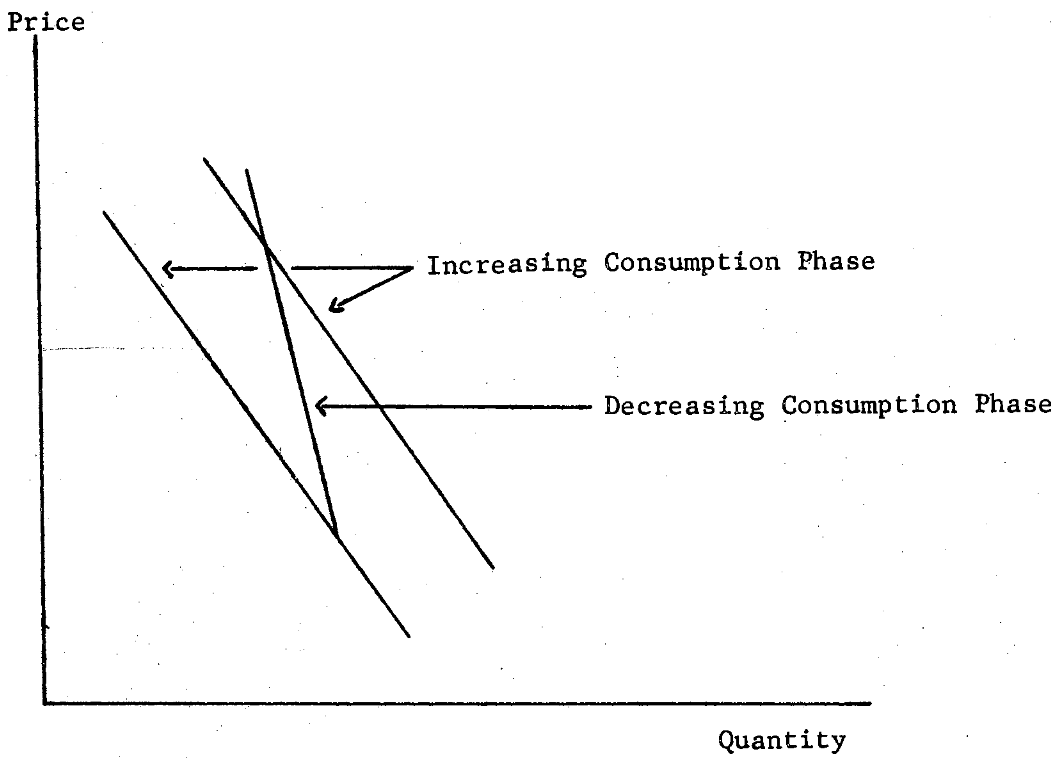

Figure 3. Schematic Illustration of "Consumption Response"

follows Katona's suggestion that consumer behavior should be investigated under a range of differing circumstances.[17] It further uses, for the purpose of predicting future consumer behavior, the existence of external supply factors such as the cyclical nature of beef production which cannot be controlled by consumers. Ferger alludes to a similar approach:

> It is possible that in demand studies, in some cases rising prices, even tho they are low (below trend) are the significant phenomena to study, along with falling prices, instead of their level compared with their trend.[18]

A few more points should be clarified in relation to the "consumption response" concept. As defined above, nothing was said about income. An increasing income during the period of decreasing prices is likely to strengthen the habit of high consumption formed during that period and might result in overadjustment, whereas declining income may offset the decreasing price effect to some degree. In the following period of increasing prices, an increasing income will probably strengthen the consumption response, whereas a period of increasing price and decreasing income might cause the response to be of smaller magnitude. In Tomek and Cochrane's terminology a situation similar to the one described by the "consumption response" is called a price-induced change in tastes. They suggest that the term "response" elasticity should be used to describe this situation.[19] It is therefore suggested that the

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[17]Katona, p. 64.

[18]Ferger, p. 46.

[19]Tomek and Cochrane, p. 730.

elasticities computed in this type of analysis for separate periods of decreasing and increasing prices should be called "response" elasticities.

It is important to stress the generality of the "consumption response" concept not only where cyclical patterns of production are years in length (beef and pork for example), but also where a seasonal pattern in production is recognized. However, it might well be possible that in the latter case the irreversibility is much less apparent, since the storage of seasonally produced commodities tends to reduce the seasonal variation in the quantity consumed over a period longer than just the relevant production period. Also, it is likely that consumers form habits of consuming a larger quantity during one season and smaller quantities during following seasons (fruits and vegetables for example). Thus, well defined but changing consumption habits may be present. This question, however, will require further investigation outside the scope of this study.

The "consumption response" concept is analogous to the "output response" concept suggested by Cochrane.[20] The response relationship on the supply side describes what will happen to the quantity offered for sale when the ceteris paribus conditions are relaxed. The "output response" concept enables the prediction of the change in quantity offered for sale as associated with some particular change in price. The reason for the irreversibility of output response is that once advanced technology has been adopted by producers it will rarely be given up. Thus, in a phase of decreasing prices the quantity offered for sale will

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[20] Willard W. Cochrane, "Conceptualizing the Supply Relation in Agriculture," Journal of Farm Economics, XXXVII (1955), pp. 1161-1176.

decline, but at a rate less rapid than the rate of expansion during a phase of increasing prices. In other words, the response curve is less elastic in the declining price phase than in the rising price phase. The "requirement" for this response situation is that the declining price phase must follow in time the rising price phase.

To summarize the similarity between the two concepts of "output response" and "consumption response", "output response" is irreversible due to fixity of technology, while the "consumption response" is irreversible because of habit formation and the resistance to breaking habits once they are established. On the supply side a period of decreasing price has to follow an increasing price phase. The reverse is true on the demand side. Thus, the time dimension is introduced in both cases. Both concepts are related to the role of response to price and income changes and result in different elasticities during each of the two phases.

Applicability to Beef Consumption

In order to empirically test the existence of the "consumption response", it is necessary to examine the demand relations for a particular commodity. As shown in Chapter I, a demand situation which appears to be irreversible in nature is observed in the beef sector. Beef production exhibits a characteristic cyclical pattern which provides a good example for testing the hypothesis of irreversibility in demand. A complete cycle of 9-12 years in length includes phases of both rising and declining prices. The cyclical pattern is predictable to a fair degree and each phase of the cycle can be considered to be a long run period so far as consumer adjustment is concerned. Another reason for choosing beef as an example to be tested is that it possesses a high rank in the consumer preference hierarchy, at least with respect to food consumption. Meats account for a major share of food expenditure. Since World War II, per capita beef consumption has increased while per capita consumption of other red meats has declined. Thus, beef is among the most important of food items--in terms of food expenditures.

CHAPTER III

METHODS AND PROCEDURE

Distributed lag models are of considerable advantage in studying problems of consumer adjustment to changes in prices and incomes. In constructing a distributed lag model it is assumed that an economic cause produces its full effect only after the lapse of time. Thus, the quantity consumed at an observed period is affected not only by prices and incomes at that period, but also by past prices and incomes. Thus, a distributed lag model which takes these effects into account seems to be appropriate for this study.

The consumption response is hypothesized to be of an irreversible form. To test this hypothesis empirically, a distributed lag model which enables the estimation of two possible types of adjustment is employed. The phenomenon of irreversible reaction is shown graphically in Figure 4. It is assumed that in time t=A, prices and income (I) have been constant over a period of time long enough for the quantity (Q) to have been fully adjusted. The actual quantity adjustment is depicted by the broken line, while the equilibrium adjustment is shown by the solid line. Thus, a constant level of Q will correspond to a constant level of I. The values of Q_{EA}, Q_{EB} and Q_{EC} at time periods A, B, and C respectively represent the equilibrium behavior of consumers with respect to the given constant values of I.[1] In the above explanation

[1]Koyck, pp. 14-15

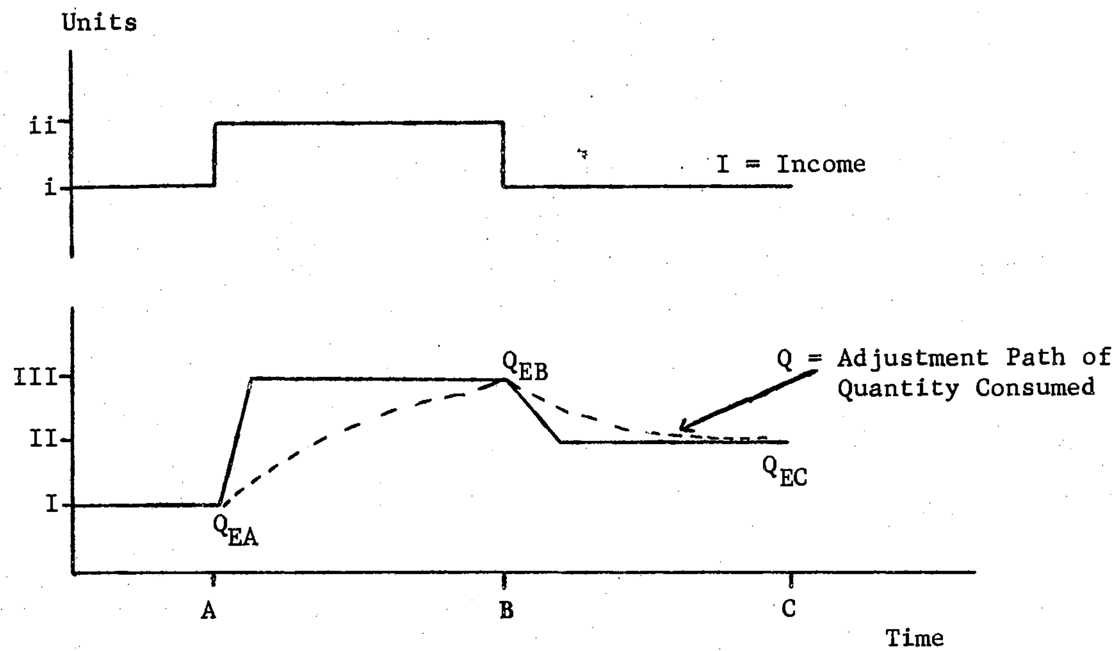

Figure 4. Irreversible Reaction. Consumers Quantity Adjustment to Income Changes, a Schematic Illustration

it is assumed that the new equilibria (at t=B and t=C) were obtained before another disturbance was introduced. The irreversible response is depicted by the new level of equilibrium at time t=C. It can be seen that after income has returned to its former level of i, and has remained constant at this level long enough for Q to reach an equilibrium, the new equilibrium (Q_{EC}) is at a higher level than was previously generated when income was constant at i (Q_{EA}).

The type of adjustment shown in Figure 4 is a lagged adjustment. However, it might be possible that consumers under certain circumstances, exhibit a different type of adjustment (Figure 5). Their first reaction to, say a decreasing price or an increasing income may be to overadjust consumption, mainly because of imperfect knowledge about the stability of the new conditions. In Figure 5 the changes in quantity versus changes in price are shown. An overadjustment is described for the period of decreasing price and a lagged adjustment for periods of increasing price (indicated by the broken lines). A third type of adjustment--namely, an immediate adjustment to the new equilibrium level of consumption associated with price or income changes--might also occur. This is depicted by the solid quantity line from t=-1 to t=0 for periods of decreasing prices, and from t=5 to t=6 for periods of increasing prices.

The Econometric Model

A distributed lag model and an estimation procedure based on Martin's application of distributed lag models was selected for use in

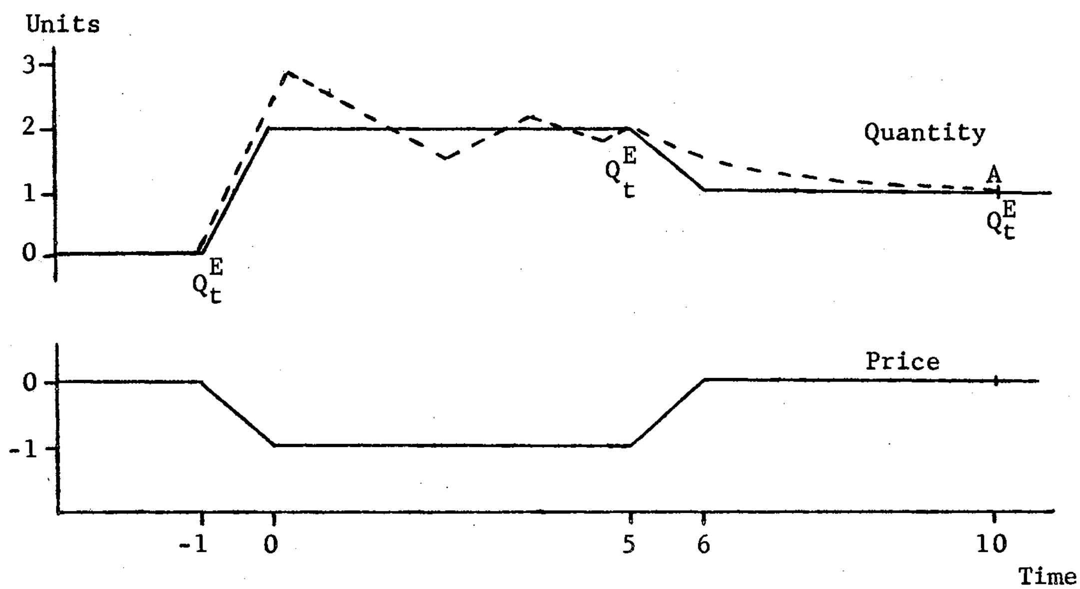

Figure 5. Possible Types of Consumers Quantity Adjustment to Price Changes

this study.[2]

The static equation for any period would be shown by (1).

$$(1) \quad Q_B = a_o + a_1X_1 + a_2X_2 + a_3X_3 + W$$

where Q_B = quantity of beef

X_1 = price of beef

X_2 = price of pork

X_3 = income

W = error term

When variables are dated, the equation for any time period is shown by (2).

$$(2) \quad Q_{Bt} = a_o + a_1X_{1t} + a_2X_{2t} + a_3X_{3t} + W_t$$

where t is the time designation and the other variables are as identified before.

Equation (2) can now be modified to a form which represents the current quantity demanded as a function of prices and incomes during the current cyclical phase and prices and incomes during the preceding cyclical phase. For example, the quantity at time period shown by point A in Figure 5 is a function of prices and incomes at time periods 5-10 and 0-5. Thus,

$$(3) \quad Q_{Bt} = a_o + a_1X_{1t} + a_2X_{2t} + a_3X_{3t} + b_1X^*_{1t} + b_2X^*_{2t} + b_3X^*_{3t} + W_t$$

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[2]James E. Martin, "An Application of Distributed Lags in Short-Run Consumer Demand Analysis" (unpub. Ph.D. dissertation, Iowa State University, 1962), pp. 9-52. See also: James E. Martin, "The Use of Distributed Lag Models Containing Two Lag Parameters in the Estimation of Elasticities of Demand," Journal of Farm Economics, XIV (1963), pp. 1474-1481.

where the asterisks represent prices and income during the cyclical phase immediately prior to the one for which Q_{Bt} is observed. If it is assumed that quantity demanded during the time period t depends on prices and incomes during period t and on prices and incomes during "all" past periods, then the demand function is shown by (4).

$$(4) \quad Q_{Bt} = a_o + \sum_{i=1}^{n} \sum_{j=0}^{\infty} a_{ij} X_{it-j} + \sum_{i=1}^{n} \sum_{j=0}^{\infty} b_{ij} X^*_{it-j} + W_t$$

Equation (4) does not presume any form of the lagged prices and incomes on the current consumption. Koyck[3] suggested that the lagged coefficients be approximated by converging geometric series. The a_{ij} and b_{ij} are given by (5).

$$(5) \quad a_{ij+1} = \lambda a_{ij} \qquad -1 < \lambda < 1 \qquad i = 1, 2, 3 \ldots n \quad j \geq 0$$

$$b_{ij+1} = \mu b_{ij} \qquad -1 < \mu < 1 \qquad i = 1, 2, 3 \ldots n \quad j \geq 0$$

Hereafter in this study the lag parameter of prices and income in periods of decreasing consumption will be designated as λ, and the lag parameter of prices and income in periods of increasing consumption will be designated as μ. It is also assumed that all lagged variables in each cyclical phase have the same lag distribution.

Equations (4) and (5) may be rewritten as (6).

$$(6) \quad Q_{Bt} = a_0 + \sum_{i=1}^{n} \sum_{j=0}^{\infty} a_{ij} \lambda^j X_{it-j} + \sum_{i=1}^{n} \sum_{j=0}^{\infty} b_{ij} \mu^j X^*_{it-j} + W_t$$

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[3]Koyck, p. 20.

In order to estimate (6) it must first be reduced by lagging each variable one period and multiplying (6) by λ.

$$(7)\quad \lambda Q_{Bt-1} = a_0\lambda + \sum_{i=1}^{n}\sum_{j=1}^{\infty} a_{ij}\lambda^{j}X_{it-j} + \sum_{i=1}^{n}\sum_{j=1}^{\infty} b_{ij}\lambda\mu^{j-1}X^{*}_{it-j} + \lambda W_{t-1}$$

Subtracting (7) from (6) results in (8).

$$(8)\quad Q_{Bt} = a_0(1-\lambda) + \sum_{i=1}^{n} a_iX_{it} + (\mu-\lambda)\sum_{i=1}^{n}\sum_{j=1}^{\infty}\mu^{j-1}b_{ij}X^{*}_{it-j} + \lambda Q_{Bt-1}$$

$$+ W_t - \lambda W_{t-1}$$

Multiplication of (8) by μ and lagging it one period results in (9).

$$(9)\quad \mu Q_{Bt-1} = a_0(1-\lambda)\mu + \mu\sum_{i=1}^{n} a_iX_{it-1} + (\mu-\lambda)\sum_{i=1}^{n}\sum_{j=2}^{\infty} b_{ij}\mu^{j-1}X^{*}_{it-j}$$

$$+ \mu\lambda Q_{Bt-2} + \mu W_{t-1} - \lambda\mu W_{t-2}$$

Subtracting (9) from (8) produces (10).

$$(10)\quad Q_{Bt} = a_0(1-\lambda)(1-\mu) + \sum_{i=1}^{n} a_iX_{it} - \mu\sum_{i=1}^{n} a_iX_{it-1} + \sum_{i=1}^{n} b_iX^{*}_{it}$$

$$- \lambda\sum_{i=1}^{n} b_iX^{*}_{it-1} + (\lambda+\mu)Q_{Bt-1} - \lambda\mu Q_{Bt-2} + U_t$$

where (10a) $U_t = W_t - (\lambda+\mu)W_{t-1} + \lambda\mu W_{t-2}$

Equation (10) is non linear in the original parameters. Thus, applying least squares procedure to (10) will not insure unique estimates of the original parameters since there are 21 normal equations for the estimation of 10 economic parameters. If the errors (W_t) in (6) are independent, then the errors (U_t) in (10) will be correlated if a lag in consumer adjustment to changes in prices and income does in fact exist. Applying least squares procedure under the assumption of independent errors to (10) will yield biased and inefficient estimates of the other variables.

It is hypothesized that the errors in (10) follow the first order autoregressive scheme as shown by (11).

$$(11) \quad U_t = \beta U_{t-1} + \varepsilon \qquad\qquad -1 < \beta < 1$$

where β is the autocorrelation coefficient and ε has the usual statistical properties of the error term in least squares estimation.

From (10) Equation (12) may be derived.

$$(12) \quad U_t = Q_{Bt} - a_0(1-\lambda)(1-\mu) - \sum_{i=1}^{n} a_i X_{it} + \mu \sum_{i=1}^{n} a_i X_{it-1} - \sum_{i=1}^{n} b_i X^*_{it} + \lambda \sum_{i=1}^{n} b_i X^*_{it-1} - (\lambda+\mu)Q_{Bt-1} + \lambda\mu Q_{Bt-2}$$

Substituting (12) into (11), (11) may be rewritten as (13).

$$(13) \quad U_t = \beta U_{t-1} + \varepsilon_t = \beta Q_{Bt-1} - a_0(1-\lambda)(1-\mu)\beta - \beta \sum_{i=1}^{n} a_i X_{it-1} + \beta\mu \sum_{i=1}^{n} a_i X_{it-2} - \beta \sum_{i=1}^{n} b_i X^*_{it-1} + \beta\lambda \sum_{i=1}^{n} b_i X^*_{it-2} - \beta(\lambda+\mu)Q_{Bt-2} + \beta\mu\lambda Q_{Bt-3} + \varepsilon_t$$

Collecting terms from (12) and (13) and adding 4 dummy variables D_K for measuring seasonality in demand results in (14).

$$(14)\quad Q_{Bt} = a_0(1-\lambda)(1-\mu)(1-\beta) + \sum_{i=1}^{n} a_i X_{it} - (\mu+\beta)\sum_{i=1}^{n} a_i X_{it-1}$$

$$+ \beta\mu \sum_{i=1}^{n} a_i X_{it-2} + \sum_{i=1}^{n} b_i X^*_{it} - (\lambda+\beta)\sum_{i=1}^{n} b_i X^*_{it-1} + \lambda\beta \sum_{i=1}^{n} b_i X^*_{it-2}$$

$$+ (\lambda+\mu+\beta)Q_{Bt-1} - [(\lambda+\mu)\beta+\lambda\mu]Q_{Bt-2} + \beta\mu\lambda Q_{Bt-3}$$

$$+ \sum_{K=1}^{4} d_K D_{Kt} + m_1 M_{1t} + m_2 M_{2t} + \varepsilon_t$$

In (14) the live-wholesale and the wholesale-retail price spreads are designated as M_{1t} and M_{2t} respectively. The demand at the wholesale level is derived from the demand at retail by subtracting the wholesale -retail price spread. Thus only M_{2t} is introduced in estimating the wholesale equation. Subtracting the wholesale-retail and live-wholesale price spreads from the demand at retail results in the derivation of the demand at the farm level. Therefore both M_{1t} and M_{2t} are introduced in estimating the demand at the farm level. There is no need to use any price spread variables in estimating the demand at retail. It is assumed that middlemen respond within a time period of a quarter, thus no lag is associated with these variables. Equation (14) can be estimated by using the autoregressive least squares method. This procedure will yield estimates which possess the large sample properties of consistency and asymptotic normality under the assumptions that the X_{it} and X^*_{it} are bounded, and the ε_t are normally distributed. Also, these estimates will be the maximum likelihood ones which are efficient if the likelihood function is unimodal.

Estimation Procedure

The variables in (14) are defined as:

Q_{Bt-j} = per capita consumption of beef (j = 0, 1, 2, 3).

$X_{1t-j} = P_{Bt-j}$ = price of beef for phases of decreasing consumption deflated by the Consumer Price Index.

$X_{2t-j} = P_{Pt-j}$ = price of pork for phases of decreasing consumption deflated by the Consumer Price Index.

$X_{3t-j} = Y_{t-j}$ = per capita income for phases of decreasing consumption deflated by the Consumer Price Index.

$X^*_{1t-j} = P^*_{Bt-j}$ = price of beef for phases of increasing consumption deflated by the Consumer Price Index.

$X^*_{2t-j} = P^*_{Pt-j}$ = price of pork for phases of increasing consumption deflated by the Consumer Price Index.

$X^*_{3t-j} = Y^*_{t-j}$ = per capita income for phases of increasing consumption deflated by the Consumer Price Index.

D_{kt} = 1 for the k^{th} quarter, otherwise zero.

M_{1t} = live-wholesale price spread deflated by the Consumer Price Index.

M_{2t} = wholesale-retail price spread deflated by the Consumer Price Index.

ε_t = errors in the equation

For all X's above j = 0, 1, 2,

t = 1, 2, 3, ... 76.

The estimation procedure as it is shown in the following section is related to the retail equation. The procedure for the wholesale and farm equations is the same except for the addition of the appropriate price spread variables (M_{1t} and M_{2t}).

When the data are converted into the form of deviations from the mean, the computation of the constant term in (14) is deferred[4] and (15) results (one dummy variable is deleted as corrected data are used).

$$(15)\quad y_{t0} = a_{10}X_{1t} + a_{20}X_{2t} + a_{30}X_{3t} - (\mu_0 + \beta_0)a_{10}X_{1t-1}$$

$$- (\mu_0 + \beta_0)a_{20}X_{2t-1} - (\mu_0 + \beta_0)a_{30}X_{3t-1} + \mu_0\beta_0 a_{10}X_{1t-2}$$

$$+ \mu_0\beta_0 a_{20}X_{2t-2} + \mu_0\beta_0 a_{30}X_{3t-2} + b_{10}X^*_{1t} + b_{20}X^*_{2t}$$

$$+ b_{30}X^*_{3t} - (\lambda_0 + \beta_0)b_{10}X^*_{1t-1} - (\lambda_0 + \beta_0)b_{20}X^*_{2t-1}$$

$$- (\lambda_0 + \beta_0)b_{30}X^*_{3t-1} + \lambda_0\beta_0 b_{10}X^*_{1t-2} + \lambda_0\beta_0 b_{20}X^*_{2t-2}$$

$$+ \lambda_0\beta_0 b_{30}X^*_{3t-2} + (\lambda_0 + \mu_0 + \beta_0)y_{t-1} - [(\lambda_0 + \mu_0)\beta_0 + \lambda_0\mu_0]y_{t-2}$$

$$+ \lambda_0\mu_0\beta_0 y_{t-3} + d_{10}D_{1t} + d_{20}D_{2t} + d_{30}D_{3t} + \varepsilon_t$$

The zero subscript in (15) designates the starting values of the unknown parameters which are used in the autoregressive least squares estimating procedure. Those values of the a_i's and b_i's are obtained from the estimation of (14) by least squares when it is assumed that all lagged variables have the same type of lag λ. Any value between -1 and +1 may be assigned to μ_0 and β_0 in (15) as a starting value.

Equation (15) is now expanded in a first order Taylor series. Thus, the resulting equation (16) uses $(y_t - y_{t0})$ as the dependent variable.

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[4]Once the parameters in (14) are estimated, the constant term is computed in the ordinary way of computing the constant in least squares procedure.

$$(16)\quad y_t - y_{t0} = \frac{\partial y_t}{\partial a_{10}}(a_{10} - a_1) + \frac{\partial y_t}{\partial a_{20}}(a_{20} - a_2) + \frac{\partial y_t}{\partial a_{30}}(a_{30} - a_3)$$

$$+ \frac{\partial y_t}{\partial b_{10}}(b_{10} - b_1) + \frac{\partial y_t}{\partial b_{20}}(b_{20} - b_2) + \frac{\partial y_t}{\partial b_{30}}(b_{30} - b_3)$$

$$+ \frac{\partial y_t}{\partial \lambda_0}(\lambda_0 - \lambda) + \frac{\partial y_t}{\partial \mu_0}(\mu_0 - \mu) + \frac{\partial y_t}{\partial \beta_0}(\beta_0 - \beta)$$

$$+ \frac{\partial y_t}{\partial d_{10}}(d_{10} - d_1) + \frac{\partial y_t}{\partial d_{20}}(d_{20} - d_2) + \frac{\partial y_t}{\partial d_{30}}(d_{30} - d_3)$$

$$+ V_t$$

Let Z_{i0} $(i = 1 \ldots 12)$ stand for the first derivative of y_t with respect to each unknown parameter, and Δa_{i0} $(i = 1 \ldots 12)$ for the difference between the selected starting value and the "true" unknown parameter. Equation (17) can then be written.

$$(17)\quad y_t - y_{t0} = \sum_{i=1}^{12} Z_{i0}\Delta a_{i0} + V_t$$

The regression of $y_t - y_{t0}$ on the Z_{i0} is now computed to get estimates of the Δa_{i0}. If the estimates of the Δa_{i0} obtained from this regression are not small, the process is repeated using a second set of trial values $a_{i0} + K\Delta\hat{a}_{i0}$, $i = 1, 2, \ldots 12$, where $\Delta\hat{a}_{i0}$ is an estimate of Δa_{i0}. The constant K is selected in such a manner that the residual sum of squares in (14) decreases for successive iterations; i.e., converges to a local minimum.[5]

The transformed variables required for the autoregressive least

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[5]Wayne A. Fuller and James E. Martin, "A Note on 'The Effects of Autocorrelated Errors on the Statistical Estimation of Distributed Lag Models'," Journal of Farm Economics, XLIV (1962), pp. 407-410.

squares estimation in (17), the Z_{i0} and $y_t - y_{t0}$, are linear functions of the original variables. Thus, it is convenient to present the estimation procedure in matrix notation.[6]

The matrix of observations of the independent variables can be defined as X, and its dimensions are 24 x 73. The matrix of observations on the 12 Z's for the first iteration is obtained from (18).

$$(18) \quad Z_0 = A_0X$$

where A_0 is a 12 x 24 matrix of the transformed variables Z_{i0}. (The values of the unknown parameters in this matrix are the starting values obtained from estimating (14) by least squares procedure). The dependent variables for the first iteration are:

$$(19) \quad y_t - y_{t0} = y_t + C_0X$$

where C_0 is a row vector of the initial coefficients in (15) with reversed signs.

Since the changes to be made in the initial estimates of the Δa_i are to be estimated, (20) is written.

$$(20) \quad Z_0Z_0'\Delta\theta_0 = A_0XX'A_0'\Delta\theta_0 = A_0X(y + C_0X)'$$

where

$$(21) \quad \Delta\theta_0 = [\Delta a_{10}, \Delta a_{20} . . . \Delta a_{120}]$$

The XX' matrix--the sum of squares and cross products matrix of the original variables, may be transformed directly into the ZZ' matrix by the

[6]Martin, An Application of Distributed Lags, pp. 37-39.

matrix multiplication $\left((A(XX'))A'\right)$.

The A and X matrices are augmented with the C_j and y vectors respectively, where C_j is the row vector of coefficients in (15) for successive iterations (j is the number of iteration). The independent and dependent variables of equation (20), and the residual sum of squares of (14) about any trial vector of estimates, may be obtained from the matrix multiplication shown in (22) and (23).

$$(22)\quad \bar{A}_j(\overline{XX'})\bar{A}_j' \qquad j = 1, 2, 3, \ldots\ldots$$

$$(23)\quad \bar{A}_j = \begin{bmatrix} A_j & 0 \\ C_j & 1 \end{bmatrix} \qquad \bar{X} = \begin{bmatrix} X \\ y \end{bmatrix}$$

where $\bar{A}_j$ and $\bar{X}$ denote the augmented matrices for the j^{th} iteration.

In the retail level model, the size and forms of the matrices are shown below.

$$\underset{(13 \times 25)}{\begin{bmatrix} \bar{A}_j \end{bmatrix}} \underset{(25 \times 25)}{\begin{bmatrix} \overline{X'X} \end{bmatrix}} \underset{(25 \times 13)}{\begin{bmatrix} \bar{A}_j' \end{bmatrix}} = \underset{(13 \times 13)}{\begin{bmatrix} R \end{bmatrix}}$$

The R matrix can be partitioned as below.

$$\left[\begin{array}{c|c} \underset{(12 \times 12)}{R_{11}} & R_{12} \\ \hline R_{21} & R_{22} \end{array}\right]$$

$$R_{11} = AX'XA'$$
$$R_{12} = AX'(y+CX)'$$
$$R_{21} = (y+CX)A'X$$
$$R_{22} = (y+CX)(y+CX)'$$

The 12 $\Delta\hat{a}_i$'s (in the form of a 12 x 1 column vector) are obtained from

(24) and (25).

$$(24)\quad AX'XA'\Delta a_i = AX'(y+CX)'$$

$$(25)\quad \Delta\hat{a}_i = [AX'XA']^{-1} AX'(y+CX)'$$

The procedure is repeated for successive trial values P_{j+1} where

$$P_{j+1} = a_{ij} + \Delta\hat{a}_{ij} \quad (i = 1, 2, \ldots 12; \quad j = 1, 2, 3 \ldots)$$

An F test is used to determine when the autoregressive least squares solution is obtained during the iteration process

$$(26)\quad t_i^2 = \frac{(\Delta\hat{a}_i)^2}{var.(a_i)} < .001 \text{ for all } i \quad (i = 1, 2 \ldots 12)$$

when $\hat{a}_i$ is the parameter being estimated. The large sample variances and covariances are estimated from the proper elements R_{ij} of the R_{11}^{-1} matrix obtained at the final iteration, and the estimated variance S^2 is calculated as shown in (27).

$$(27)\quad S^2 = \frac{(y+CX)(y+CX)'}{n-r}$$

In equation (27), n is the number of observations (73 in this case) and r is the number of the parameters (12 in this case). A "t" test for the significance of the parameters is computed as shown in (28).

$$(28)\quad t_{\alpha/2} = \frac{\hat{a}_i - 0}{var.(\hat{a}_i)}$$

The length of time needed for consumers to adjust actual consumption to within 95 per cent of a new equilibrium can be estimated for the periods of decreasing and increasing consumption from the lagged variables λ and μ respectively.

$\lambda^n = .05$

$n \log \lambda = \log .05$

$n = \frac{\log .05}{\log \lambda}$ for decreasing consumption period

$n = \frac{\log .05}{\log \mu}$ for increasing consumption period

where n is the number of time periods needed for adjustment.

The Data

The statistical model presented above is used to estimate the consumption response at the retail, wholesale, and farm levels. Fox argues that the production of meats is largely predetermined, thus the least squares regression of retail prices of meat on meat consumption is not likely to be seriously biased.[7] Also, the effects of livestock prices during the marketing year upon the current production of meat are generally relatively small. This is particularly true in the case of demand for beef, especially if quarterly observations are used. A similar assumption was made by Logan and Boles in a study on quarterly fluctuations in retail prices of meat.[8] Martin[9] has shown that the conventionally formulated distributed lag model will frequently produce seriously biased elasticity estimates. The nature of the bias is highly dependent on whether price or quantity is used as the dependent variable.

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[7] Karl A. Fox, "The Analysis of Demand for Farm Products," U.S.D.A. Technical Bulletin No. 1081, September 1953, p. 39.

[8] Samuel H. Logan and James N. Boles, "Quarterly Fluctuations in Retail Prices of Meat," Journal of Farm Economics, XLIV (1962), p. 1050.

[9] Martin, "Isolation of Lagged Economic Responses," To be published in The Journal of Farm Economics, February 1967.

However, in the more general distributed lag models of the type used in this study, the short-run and long-run elasticity estimates appear to be less seriously biased than the comparable estimates produced by the conventional distributed lag models, regardless of whether price or quantity is used as the dependent variable. Since the consumption response relationship is observed with regard to per capita consumption, and further since Martin has shown that the choice of quantity or price as the dependent variable in the more general model makes little difference in the statistical validity of the results, quantity consumed has been used in this study as the dependent variable.

Per capita beef consumption data were available on a quarterly basis only for the period 1955-1964, whereas annual per capita consumption data were available for the entire period. The quarterly percentage distribution of the annual quantity for the years 1955-1964 shows little variation. This distribution was used as the criterion for distributing the annual consumption for the remaining years on a quarterly basis.

The independent variables are represented by the price of beef, price of pork, and disposable income. The effect of the increase in population during the observed years is taken into account by using per capita consumption and personal disposable income. Two price spread variables, live-wholesale and wholesale-retail are added to the basic retail model for estimating the farm equation. The wholesale-retail margin alone is used in estimating the demand at the wholesale level. All prices, income, and margins are deflated by the Consumer Price Index (1957-59 = 100), in order to minimize the effect of changes in the value of the dollar during the period analysed.

Observations for the years 1947-1965 are employed in this study. The reason for selecting this period was to study the situation in "normal" years, namely not to include the war period in which price controls prevailed. Quarterly data are used since seasonal differences in demand are of casual interest, and since the use of annual data would not provide enough degrees of freedom for purposes of testing the significance of the estimated parameters.

The quarterly observations of prices and margins were computed as simple averages from monthly data published by the U.S.D.A. (Livestock and Meat Statistics). The quantity data were obtained from U.S. Food Consumption (U.S.D.A.).

Quarterly price data for beef and pork at the farm level were computed from the prices paid for cattle and hogs slaughtered under Federal inspection. Average wholesale price per 100 pounds of choice grade steer carcasses (600-700 pounds) in the New York market, and the average wholesale value of hog products derived from 100 pounds live hog were used for estimating the demand at the wholesale level. The U.S. average retail price per pound of beef and pork were employed in the retail level equation.

Quarterly per capita disposable personal income data were obtained from "Economic Indicators" published by the Joint Economic Committee (U.S. Government). The deflated data as they were used in the actual estimation procedure are given in Appendix C.

Inspection of Figure 1 indicates that for the period analysed (1947 -1965), three phases of decreasing consumption and two phases of increasing consumption prevailed. In order to estimate the parameters in the model presented above, the data were split according to the decreasing and increasing consumption phases. Table I illustrates schematically the manner in which the data were split and set up for estimation purposes at the retail level. For estimation of the farm and wholesale equations, the form is basically the same except for assigning the appropriate values of M_{1t} and M_{2t}. The asterisks in P^*_{Bt-j}, P^*_{Pt-j} and Y^*_{t-1} indicate the relevant observations for phases of increasing consumption. The data for phases of decreasing consumption are represented by P_{Bt-j}, P_{Pt-j} and Y_{t-j}. The X's stand for the observations on the various variables. Thus, for periods of decreasing consumption, the quarterly observations on prices and income are plugged in the left side of the table whereas prices and income for opposite conditions take zero values. The situation is reversed in the following period. The prices and income observations in the last quarter in each period are used as the first set of data in the following period to indicate the transition from one phase to the other. For P_{Bt-j}, P_{Pt-j}, Y_{t-j} and P^*_{Bt-j}, P^*_{Pt-j}, Y^*_{t-j}, $j = 0, 1, 2$. D_{ti} represents the appropriate quarter observed, $i = 1, 2, 3, 4$. For the first quarter $D_{t1} = 1$ and D_{t2}, D_{t3}, D_{t4} are zero, for the second quarter $D_{t2} = 1$ and D_{t1}, D_{t3}, D_{t4} are zero, etc. M_{1t} and M_{2t} have the appropriate observations at the farm and wholesale equations.

TABLE I

DATA FORMAT FOR DISTRIBUTED LAG ANALYSIS OF CONSUMPTION RESPONSE FOR BEEF AT THE RETAIL LEVEL

t	P_{Bt-j}	P_{Pt-j}	Y_{t-j}	P^*_{Bt-j}	P^*_{Pt-j}	Y^*_{t-j}	Q_{Bt-j}	D_{ti}	M_{1t}	M_{2t}	Q_{Bt}
Decreasing Quantity Period	X	X	X	0	0	0	X	X	-	-	X
	X	X	X	0	0	0	X	X	-	-	X
	X	X	X	0	0	0	X	X	-	-	X
	X	X	X	X	X	X	X	X	-	-	X
Increasing Quantity Period	0	0	0	X	X	X	X	X	-	-	X
	0	0	0	X	X	X	X	X	-	-	X
Decreasing Quantity Period	X	X	X	X	X	X	X	X	-	-	X
	X	X	X	0	0	0	X	X	-	-	X
	X	X	X	0	0	0	X	X	-	-	X

CHAPTER IV

RESULTS AND INTERPRETATION

In this chapter the results of the estimation procedure are presented and analysed. As explained earlier the model was applied to the demand function at the retail, wholesale and farm levels. The results are presented in the same order. The economic meaning and statistical validity of the estimated parameters is explained, and the signs and magnitudes of the lag parameters are interpreted with respect to the type of consumer adjustment. The seasonal intercepts are calculated and their significance is tested. Long-run response elasticities are computed for the separate periods, and for the general cases of decreasing and increasing consumption assuming equilibrium conditions. The length of time needed for consumers to adjust consumption to within 95 per cent of a new equilibrium is calculated. Finally, conclusions are drawn concerning the agreement with the tested hypothesis.

Demand for Beef at Retail

Inspection of the results in Table II indicates that the parameters associated with the price of beef and the level of income (P_B, P_B^*, Y, and Y* respectively) are significantly different from zero in both phases, and that the directions (signs) of the relationships agree with logical expectation. The parameters associated with the price of pork (P_P and P_P^*) are insignificant and their standard errors exceed the value of these parameters. The negative sign of P_P and P_P^* may be due to intercorrelation between prices of pork and beef, and income. The statistical non-significance of the parameters suggests that for practical purposes in this analysis the effect of the price of pork upon the demand for beef may be ignored.

The lag parameter (λ) for price and income in the decreasing consumption phase is significant and positive. The adjustment coefficient for periods of decreasing consumption is defined as $\gamma_\lambda = 1-\hat{\lambda}$. The fact that $\gamma_\lambda < 1$ ($\gamma_\lambda = 1 - .88825 = .11175$) indicates that consumer reaction during phases of decreasing consumption and increasing price is lagged.

The lag parameter for price and income in increasing consumption phases (μ) is insignificant and negative. The negative sign per se suggests that consumers tend to overadjust since the adjustment coefficient for this period is larger than one. ($\gamma_\mu = 1 - \hat{\mu} = 1.23623$). However the insignificance of $\hat{\mu}$ indicates that consumption is adjusted immediately during a phase of declining prices and increasing consumption.

The different types of consumer adjustment as expressed by the values of γ_λ and γ_μ prevent the rejection of the hypothesis that consumer response to changes in price and income is different in phases of increasing price than in phases of decreasing price. More specifically, the results suggest a lag response in phases of increasing price and immediate response during phases of declining price. This situation during the increasing price phase can be explained as the persistence of habits formed during the preceding phase of declining prices. Thus, the hypothesis that the long run demand for beef at the retail level is irreversible in nature is supported.

TABLE II

ESTIMATED PARAMETERS OF THE RETAIL DEMAND FOR BEEF[a]

P_B	P_P	Y	λ	P^*_B	P^*_P	Y^*	μ
-.02752** (.01301)	-.00008 (.01203)	.00117** (.00048)	.88825* (.05276)	-.17720*** (.03418)	-.02015 (.03042)	.00923*** (.00175)	-.23623 (.20161)
d_2	d_3	d_4	β	R^2	Constant	MSE[b]	
.76168*** (.19094)	1.61932*** (.20847)	.48077* (.25617)	-.14478 (.24103)	.9774	2.42472	.28513	

[a]Standard errors are presented in parentheses below the respective parameters

*Significantly different from zero at less than 10 per cent level

**Significantly different from zero at less than 5 per cent level

***Significantly different from zero at less than 1 per cent level

[b]MSE is the mean square of errors which is an estimate of the unexplained variance

The seasonal differences in demand can be examined by computing the quarterly intercepts. The constant term (C) indicates the first quarter intercept, and $C + d_i$ (where i = 2, 3, 4) shows the intercepts for the other three quarters. This computation result in $C = 2.42$, $d_2 = 3.18$, $d_3 = 4.04$, $d_4 = 2.90$. These results indicate that the demand is highest in the third quarter (summer months). The difference between the highest demand and the lowest--in the first quarter--is approximately 1.6 pounds per quarter. Tests of the differences between the quarterly intercepts indicate that the third intercept is significantly different from the second and fourth intercepts. The results for the shifts in seasonal demand are not completely consistent with the estimates reported by Martin[1], Logan and Boles[2] and Stanton[3]. The inconsistency is probably due to the derivation of part of the quarterly consumption data. As explained in the preceding chapter, the quarterly distribution of the quantity consumed during 1955-1964 was used as a criterion for distributing the annual data for the remaining years. In eight out of the ten years for which quarterly consumption data were available the consumption was the highest during the third quarter. By imputing the same consumption pattern to the remaining years, the third quarter was assured to be the highest with regard to seasonal consumption. However, seasonal shifts in demand are not of major concern to this study and these results should not be interpreted as indicating a change in the seasonal pattern of demand for beef. The autocorrelation coefficient

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[1]Martin, An Application of Distributed Lags, pp. 66-68.

[2]Logan and Boles, pp. 1054-1055.

[3]B. F. Stanton, "Seasonal Demand for Beef, Pork and Broilers," Agricultural Economics Research, January 1961, pp. 1-14.

is negative and nonsignificant. Thus, the hypothesis of first order autocorrelation among the errors is rejected.

The high value of R^2 (.9774) and the small magnitude of the mean square of errors (.28513) indicates that the model employed in this study should be highly reliable as a predictive model. On the basis of these results, the use of this model employing quarterly data may thus be of aid in improving the predictions of the quantity of beef demanded for a given quarter in the short run. The structure and format of the statistical model provide leading indicators in the income and price lags as well as in the lagged consumption variables.

Since as Tomek and Cochrane and Martin have shown, consumers tend to fully adjust consumption to price or income changes within a period of a year, each of the periods of increasing and decreasing consumption should be considered as long run periods. Thus, the elasticities presented in Table III should be considered as long run elasticities. Periods I, III, and V represent phases of decreasing consumption and periods II and IV represent phases of increasing consumption. The fact that the model assumed the same type of lag for income and price changes for each phase causes the consumption response to be a joint result of both factors. In other words, from this model it is not possible to separate the consumption response according to the two factors that are assumed to cause it, namely price and income changes. Therefore, the estimates presented in Table III should only be considered as reference points, and are primarily of interest for comparing their directions over time. It can be seen that in period I, III, and V, the own price elasticity is less than in periods II and IV. This agrees with the hypothesis that consumers adjust consumption by less during the

TABLE III

LONG RUN RESPONSE ELASTICITIES FOR THE SEPARATE PERIODS AT THE RETAIL LEVEL

Period	I	II	III	IV	V
Years	1947-51	1952-56	1957-59	1960-64	1965
Own Price Elasticity	-.15853	-.70060	-.10451	-.59127	-.08233
Income Elasticity	.11813	.81468	.10473	.79584	.10251

increasing price phase than during the decreasing price phase. In both phases the elasticities decline over time. This probably is the result of a broader range of quantities being included in the relatively inelastic portion of the demand curve over time. Income elasticities are higher in periods of decreasing price which indicates a stronger response to income changes in these periods. Income elasticities also decline over time. This phenomenon is probably due to the fact that a declining proportion of income was spent on beef, since income was increasing throughout the range of the data.

In order to estimate the magnitude of consumers' response in the different phases as a general case in the long run, an equilibrium situation is assumed. Under this assumption, the following conditions must prevail.

$$P_{Bt} = P_{Bt-1} = P_{Bt-2}$$

$$P_{Pt} = P_{Pt-1} = P_{Pt-2}$$

$$Y_t = Y_{t-1} = Y_{t-2}$$

$$Q_{Bt} = Q_{Bt-1} = Q_{Bt-2} = Q_{Bt-3}$$

By holding prices and income constant at an assumed equilibrium level, it is possible to compute the equilibrium quantities in both phases, and then to estimate average long run response elasticities for these equilibrium conditions. The elasticity computed for each phase under the same equilibrium conditions permits a comparison of the differences in consumer response.

Table IV presents the results of the response elasticity estimates under three sets of equilibrium conditions. The conditions first assumed

TABLE IV

RESPONSE ELASTICITIES UNDER EQUILIBRIUM CONDITIONS AT THE RETAIL LEVEL

Assumed Equilibrium Conditions	A Decreasing consumption phase	B Increasing consumption phase	Elasticity B / Elasticity A
$P_B^E = 80.62$[1]	$Q_E = 30.85$	$Q_E = 34.73$	
$P_P^E = 62.60$			
$Y^E = 1,861$	Elasticity = -.07186	Elasticity = -.41133	5.7240
$P_B^E = 76.33$[2]	$Q_E = 31.84$	$Q_E = 35.24$	
$P_P^E = 58.74$			
$Y^E = 1,838$	Elasticity = -.06593	Elasticity = -.38384	5.8219
$P_B^E = 78.90$[3]	$Q_E = 31.32$	$Q_E = 34.97$	
$P_P^E = 60.44$			
$Y^E = 1,856$	Elasticity = -.06927	Elasticity = -.39974	5.7707

[1]The assumed equilibrium conditions represent average prices and income during periods I, III and V.

[2]The assumed equilibrium conditions represent average prices and income during periods II and IV.

[3]The assumed equilibrium conditions represent average prices and income for the entire period (1947-1965).

to represent an equilibrium are the average prices and income during periods I, III, and V; the second, average prices and income for periods II and IV; and last the overall averages of prices and income during the entire period. The results indicate that during phases of decreasing consumption and increasing price, the response is less elastic than during phases of increasing consumption and decreasing price. In the phase of increasing consumption the response is approximately six times more elastic than in the phase of decreasing consumption. These results again prevent rejection of the hypothesis and indicate that the long run demand function for beef is probably of an irreversible form.

The estimates of the length of time needed for the consumers to adjust actual consumption to within 95 per cent of a new equilibrium in periods of increasing price is approximately 25 quarters. In periods of decreasing price, the periods needed for adjustment to within 95 per cent of a new equilibrium is approximately 2 quarters. This assumes that no disturbance will occur during the period of adjustment to the conditions caused by the original disturbance.

The Wholesale Level

The estimates obtained from the wholesale equation are generally consistent with the retail estimates and support the acceptance of the hypothesis. Thus, it is necessary only to point out the differences in this equation as compared with the retail analysis.

The wholesale equation was estimated using raw sums of squares and cross products. Inspection of Table V indicates that the parameters for price of beef and income are significant at both phases. Their signs also agree with *a priori* expectation. The parameters associated with the price of pork are insignificant. As in the retail level λ is positive and significant and indicates a lagged adjustment for phases of decreasing consumption. The lag parameter for decreasing price phase (μ) is negative. But μ is significant at the 10 per cent level, which indicates an overadjustment during this phase. Inspection of the quarterly intercepts in Table V shows that the demand is the highest during the third quarter. Tests of the differences between the quarterly intercepts indicate that only the third intercept is significantly different from the first intercept. These results again are not completely consistent with the estimates reported by the authors mentioned in the previous section. The reason for this inconsistency as explained earlier is probably due to the method of deriving part of the quarterly consumption data. As expected the wholesale-retail price spread (M_2) is positive and significant which indicates that the demand at wholesale is in fact closely related to the demand at retail. The autocorrelation coefficient β is negative and significantly different from zero. Thus, there is no evidence to reject the hypothesis of first order autocorrelation among the errors. The predictive quality of the model is improved nominally when compared with the retail model in that R^2 (.9999) is increased slightly, and MSE is substantially reduced (.03032).

The results shown in Table VI are consistent with the long run response elasticities given in Table III in the preceding section. It can be seen that for each period the own price and income elasticities are smaller when compared with the comparable estimates at the retail level. This is to be expected since price spreads in the packing industry tend to be larger during periods of large volumes and relatively low prices.

TABLE V

ESTIMATED PARAMETERS OF THE WHOLESALE DEMAND FOR BEEF[a]

P_B	P_P	Y	λ	P^*_B	P^*_P	Y^*	μ
-.02268***	-.00986	.00053***	.90511***	-.15866***	-.01700	.00390***	-.12097*
(.00531)	(.00725)	(.00011)	(.01575)	(.00949)	(.01665)	(.00052)	(.06146)
d_1	d_2	d_3	d_4	M_2	β	R^2	MSE[b]
1.88354***	2.58840***	3.42770***	2.34458***	.17325***	-.26978***	.9999	.03032
(.41495)	(.41322)	(.41647)	(.42431)	(.05489)	(.06948)		

[a]Standard errors are presented in parentheses below the respective parameters

*Significantly different from zero at less than 10 per cent level

***Significantly different from zero at less than 1 per cent level

[b]MSE is the mean square of errors which is an estimate of the unexplained variance

TABLE VI

LONG RUN RESPONSE ELASTICITIES FOR THE SEPARATE PERIODS AT THE WHOLESALE LEVEL

Period	I	II	III	IV	V
Years	1947-51	1952-56	1957-59	1960-64	1965
Own Price Elasticity	-.08482	-.38352	-.04971	-.28478	-.03596
Income Elasticity	.05351	.34423	.04744	.33627	.04644

The same relationships and general direction of the response elasticities exist in the wholesale equation as were observed in the retail equation.

The results presented in Table VII are the response elasticities under equilibrium conditions. They reflect the same pattern as the retail equation and again show a lower response during phases of decreasing consumption. Compared with the comparable estimates at retail, the ratio of response elasticities during phases of increasing consumption in relation to the response elasticities during phases of decreasing consumption is approximately 7:1--somewhat higher than the ratio at the retail level.

The length of time required to adjust actual consumption to within 95 per cent of a new wholesale equilibrium is approximately 30 quarters in periods of increasing price, and 2 quarters in periods of decreasing price. It is thus concluded that the hypothesis of different types of consumer adjustment to price or income changes in the two phases of the beef cycle also cannot be rejected at the wholesale level. A lagged adjustment in periods of increasing price and decreasing consumption is apparent, and the long run demand function for beef at wholesale is probably of an irreversible nature.

The Farm Level

Estimates of the parameters of the farm level equation are presented in Table VIII. The fact that almost all the estimated parameters (except P_B, Y, μ and M_1) are not significantly different from zero suggests that the form of the model used to estimate the farm equation is inappropriate. The positive sign and significance of μ indicate a

TABLE VII

RESPONSE ELASTICITIES UNDER EQUILIBRIUM CONDITIONS AT THE WHOLESALE LEVEL

Assumed Equilibrium Conditions	A Decreasing consumption phase	B Increasing consumption phase	Elasticity B / Elasticity A
$P_B^E = 47.51$[1]			
$P_P^E = 22.77$	$Q_E = 75.83$	$Q_E = 72.91$	
$Y^E = 1,861$			
Marketing Margin=2.54	Elasticity = -.01422	Elasticity = -.10338	7.2700
$P_B^E = 43.86$[2]			
$P_P^E = 19.96$	$Q_E = 75.28$	$Q_E = 73.63$	
$Y^E = 1,838$			
Marketing Margin=2.86	Elasticity = -.01288	Elasticity = -.09452	7.3385
$P_B^E = 46.05$[3]			
$P_P^E = 21.65$	$Q_E = 76.48$	$Q_E = 73.51$	
$Y^E = 1,856$			
Marketing Margin=2.71	Elasticity = -.01367	Elasticity = -.09939	7.2709

[1]The assumed equilibrium conditions represent average prices, income and marketing margin for periods I, III and V.

[2]The assumed equilibrium conditions represent average prices, income and marketing margin for periods II and IV.

[3]The assumed equilibrium conditions represent average prices, income and marketing margin for the entire period (1947-1965).

TABLE VIII

ESTIMATED PARAMETERS OF THE FARM DEMAND FOR BEEF[a]

P_B	P_P	Y	λ	P_B^*	P_P^*	Y^*	μ
-.30778***	.03872	.00327***	-.05607	-.02731	.00741	.00039	.87879***
(.06225)	(.04689)	(.00116)	(.20180)	(.02252)	(.01906)	(.00035)	(.04572)

d_1	d_2	d_3	d_4	M_1	M_2	β	R^2	MSE[b]
.48068	1.31231	1.25160	.04586	.40139**	.08212	-.21061	.9994	.28563
(1.26089)	(1.26944)	(1.25651)	(1.25251)	(.15414)	(.04928)	(.23245)		

[a]Standard errors are presented in parentheses below the respective parameters

**Significantly different from zero at less than 5 per cent level

***Significantly different from zero at less than 1 per cent level

[b]MSE is the mean square of errors which is an estimate of the unexplained variance

lagged adjustment for periods of increasing quantity and decreasing price. This is inconsistent with the results obtained in the two former equations. The fact that the parameters P_B^* and Y^*, which are associated with μ are not significantly different from zero strengthen the suspicion that this is not the real type of adjustment. The value of R^2 is .9994 and of the mean square of errors is .28563. Although the estimated parameters can not be regarded as explaining the structural equation this model should be useful for purposes of short-run prediction.

Various possibilities may account for the unexpected results at the farm level. It might be possible that the error structure follows a second order autoregressive scheme, and that a model containing this error structure should be employed. It is also possible that some variables indicating the supply conditions should be incorporated in estimating the response at the farm level. This suggests that use of a simultaneous equation model might be an appropriate approach to investigate the problem at this level. Further investigation using different models and the appropriate assumptions will be necessary if the question is to be adequately answered.

CHAPTER V

SUMMARY AND CONCLUSIONS

The idea of irreversibility in consumer response is mentioned in the literature implicitly and explicitly, although in most cases not explored empirically. Irreversibility, as it is related to demand relations, means that consumers under certain conditions of increasing income or decreasing price increase consumption of some commodities at a given rate, but these same consumers are reluctant to decrease consumption at the same rate as it was expanded when the conditions of price or income are changed. They will reduce consumption but at a rate lower than that in which they previously increased it. Persistence of habit seems to be the main cause for this type of behavior. Consumers become accustomed to high levels of consumption (which in the case of beef suggests an increasing standard of living) during periods of decreasing price or increasing income. Resistence to the changing of this habit inhibits consumer response under opposite conditions in the succeeding period. The effect of consumption habit on demand is of considerable importance. Changing habits affect the demand function by causing a change in the structural parameters of tastes and preferences which are major determinants of demand.

A consumption response concept is developed in this study which describes the irreversible nature of the demand function for beef. This concept may have relevance for other commodities which show cyclical patterns of production and price, and may provide a description of a general phenomenon which might exist in commodities other than beef. Different types of consumer adjustment to price and income changes are associated with the irreversible demand function. Those differences appear to be generated by forming certain consumption habits and by the uncertainty of consumers with respect to the stability of the price and income changes.

The purpose of this study was to test empirically whether the demand function for beef is of an irreversible form, and whether consumer adjustment to price and income changes is different in the two phases existing in the production and price cycles. Specifically, the stated hypothesis was that in the decreasing price phase of the price cycle, consumers increase consumption and form a habit of consuming at a certain rate. In the following phase of increasing price, habit persistence causes consumer to reduce the quantity demanded at a rate lower than that at which it was expanded. Thus the price elasticity of demand during periods of increasing price and decreasing quantity is shown to be smaller than during periods of decreasing price and increasing consumption.

To test this hypothesis, a distributed lag model with two lag parameters was employed. These parameters, λ and μ, enabled the estimation of the types of consumer adjustment in the two phases of the cycle. The model is non-linear in the parameters and the errors are hypothesized to be of a first order autoregressive scheme. The autoregressive least squares method was used to estimate the various parameters. Dummy variables were included to estimate seasonal differences in consumer demand. Quarterly observations of the price of beef, per capita beef consumption, price of pork, disposable personal income, and marketing margins over the period 1947-1965 were used to estimate the demand equations at the retail, wholesale, and farm levels.

The results obtained for the response at both the retail and wholesale levels indicate the existance of a consumption response of an irreversible form. At retail the response elasticity in the decreasing price phase is approximately six times greater than the response elasticity in the increasing price phase. At wholesale this ratio is approximately 7:1.

During the increasing price phase, consumer adjustment is significantly lagged. This is apparent at both the retail and wholesale levels. During the decreasing price phase, consumer adjustment is immediate at the retail level, but an overadjustment seems to occur at the wholesale level. At the wholesale level, the lag parameter associated with the declining price period (μ) is significantly different from zero at the 10 per cent level. The results in the farm level are inconsistent with the two former equations and suggest that the hypothesis of irreversible demand should be rejected at that level. However, since farm demand is derived from the demand at retail via the demand at wholesale, it is possible that a model which includes some of the supply variables such as production costs and alternatives and opportunity costs, might indicate the existance of the irreversible response at the farm level.

The main conclusion that can be drawn from this study is that the demand function for beef should be regarded as an irreversible function. This implies that the price elasticity of demand for beef is higher in periods of decreasing prices than in periods of increasing prices. The concept of consumption response as defined in Chapter II seems to contribute to the explanation of the demand relation for beef. Its existance should be taken into account when analyzing problems of demand and prices during a given phase of the beef cycle, and especially when the "turning point" of the cycle is near. Further, consumption habits--the factor which is most likely to cause this type of consumer behavior--appear to be of importance in anticipating the future. The small response elasticity during periods of increasing prices and the relatively long period of time needed to reach a new equilibrium situation suggest that most of the adjustment is made through bidding prices up. In this fashion consumers enable themselves to continue to indulge their increasing preference for beef.

Several implications of these results might be of interest to the beef industry and to marketing firms. It should be recognized that changes in demand for beef become apparent at fairly distinct time intervals. Consumers respond to price increases during the phase of decreasing consumption at a remarkably low rate. This should be taken into account by marketing firms in planning and timing long-run managerial and investment policies. The main short run implication is that the current positions of the production and price cycles should be taken into account in predicting prices for short run purposes. During a cyclical phase in which price is decreasing and consumption increasing, the considerations for making a prediction are different than for the reverse conditions. In other words, in predicting a beef price for the short run period the nature of the relevant long run demand function for beef should be defined.

Limitations of the Study and Suggestions for Further Work

In this study the assumption that the lag distribution associated with price changes is the same as that associated with income changes in each phase was made. This may not be the case in the real world, and can result in a confounded effect of income and price on the type of adjustment. Using this model and making different assumptions about the price and income lag distribution (which requires a different data format) would add to the knowledge of consumer behavior in this type of analysis and should therefore be further explored. Another limitation of this study results from the fact that the data for the time period analyzed are all associated with conditions in which income shows a strong upward trend. Because of the relationship between beef consumption and level of income, an upward trend in income tends to increase beef consumption continuously and to enhance the formation of habits of high beef consumption. Theoretically at least, income may decrease. The reaction of consumers in a situation of declining incomes might affect the formation of habits in a manner different from that examined within the scope of this study.

Further investigation into irreversible demand functions is needed. In the beef sector, the response in the farm level should be further examined using different models assuming different error structures such as a second order autoregressive error scheme. The applicability of the consumption response concept to other commodities which are cyclical in nature should be investigated to broaden the knowledge of consumer demand for various commodities.

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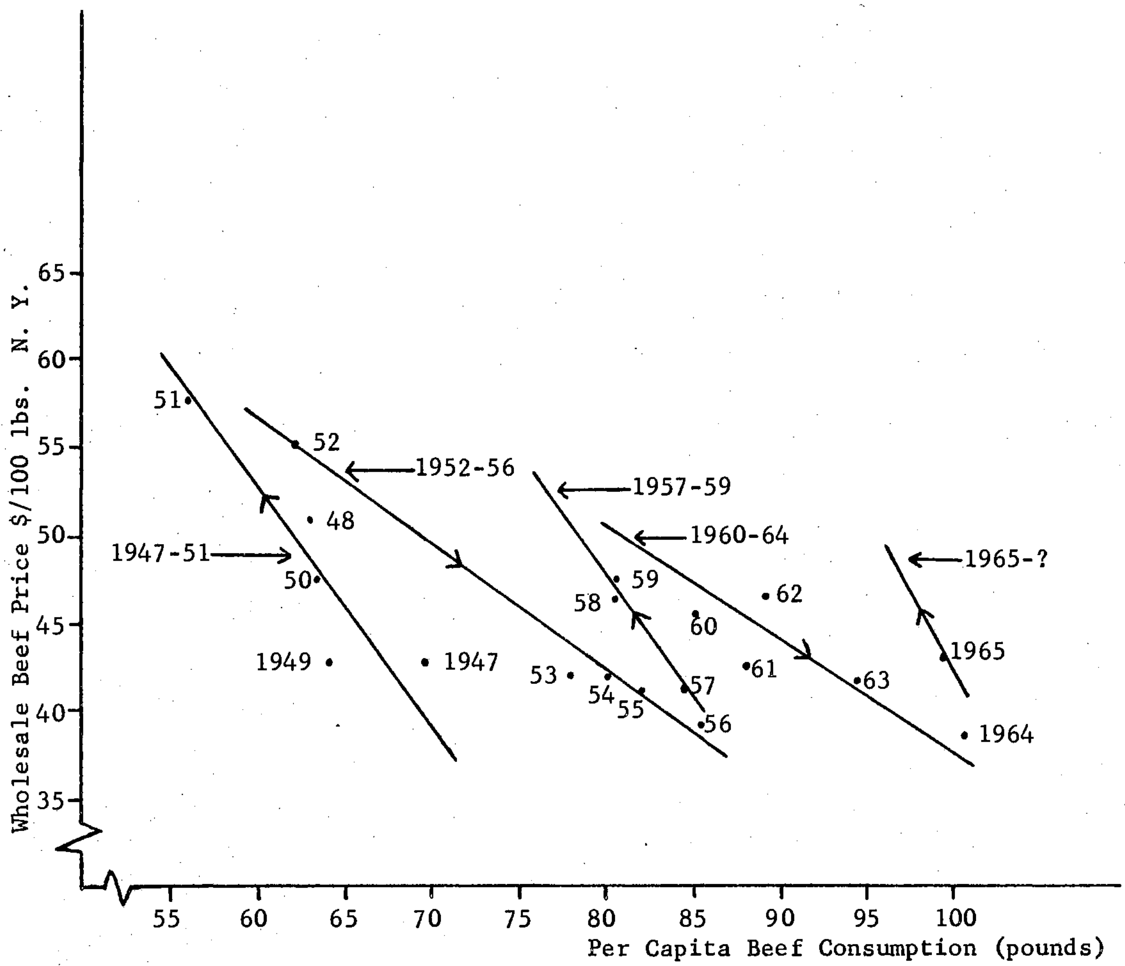
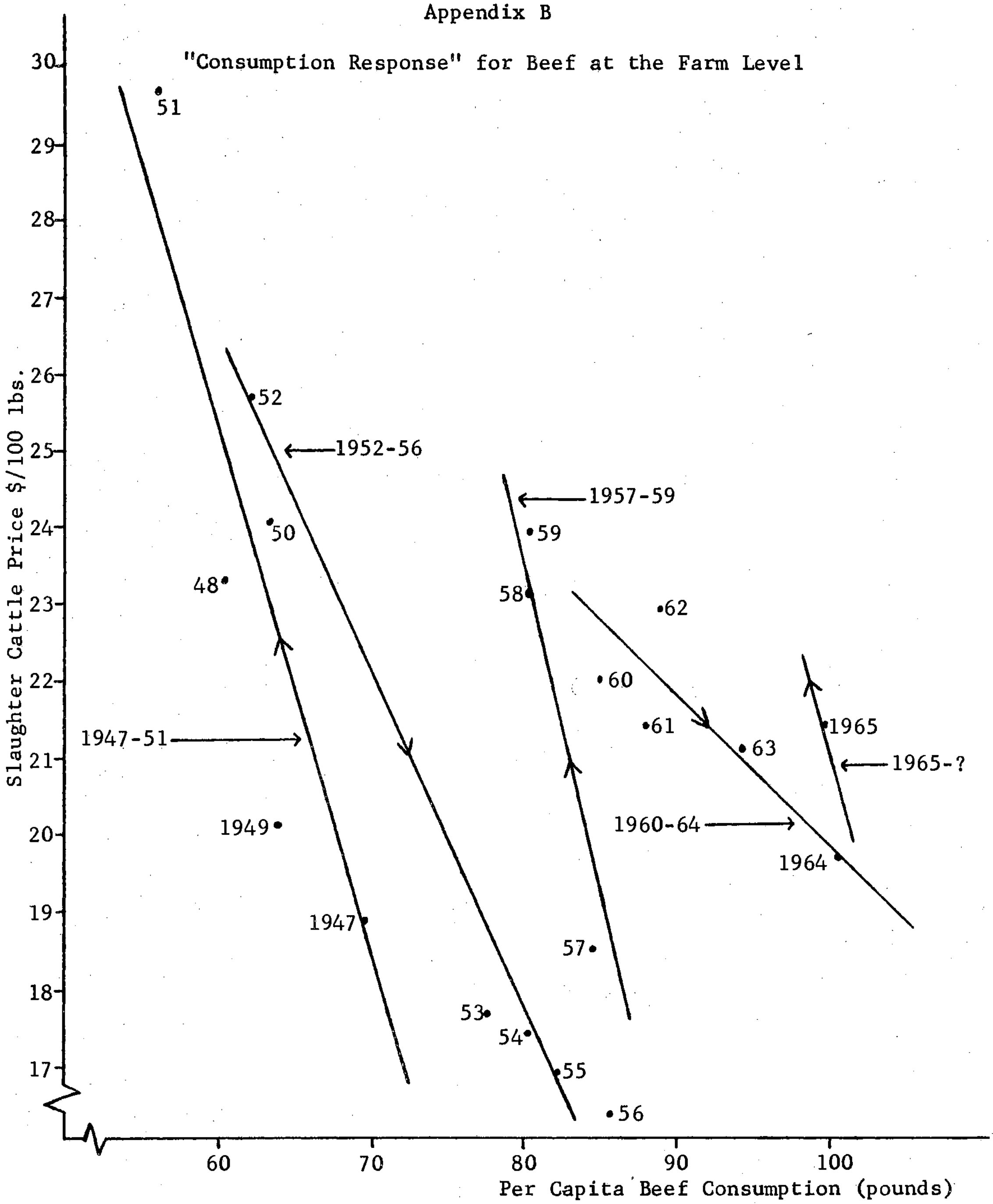
Appendix A

"Consumption Response" for Beef at the Wholesale Level



Appendix B

"Consumption Response" for Beef at the Farm Level



APPENDIX C

RETAIL, WHOLESALE AND FARM PRICES FOR BEEF AND PORK, PER CAPITA BEEF CONSUMPTION LIVE-WHOLESALE, WHOLESALE-RETAIL PRICE SPREADS, PERSONAL INCOME. DEFLATED QUARTERLY DATA 1947-1965

Year	Q_B [1]	P_{BR} [2]	P_{BW} [3]	P_{BF} [4]	P_{PR} [5]	P_{PW} [6]	P_{PF} [7]	M_1 [8]	M_2 [9]	Y [10]
1947	16.8	72.94	50.30	23.36	75.73	34.86	33.13	1.90	14.63	1,573
	17.3	75.82	51.30	25.74	75.16	33.29	30.16	1.95	14.01	1,529
	17.9	85.60	59.45	24.80	81.42	36.73	31.08	2.30	15.20	1,542
	17.6	82.92	57.25	23.18	79.46	34.64	32.54	2.10	15.48	1,542
1948	15.3	81.60	55.22	27.01	71.86	32.25	28.93	2.78	13.24	1,520
	15.6	90.05	62.10	30.34	71.94	31.11	25.77	3.39	14.59	1,554
	16.2	97.42	67.37	28.96	78.19	35.31	31.40	2.20	19.55	1,557
	16.0	90.17	57.20	25.25	72.16	29.29	27.26	1.95	19.95	1,573
1949	15.5	77.88	46.72	24.92	66.71	27.19	23.81	2.17	15.55	1,538
	15.8	81.23	49.94	26.79	67.99	25.88	22.43	2.73	14.30	1,521
	16.4	85.16	53.60	24.81	71.05	27.85	23.45	3.41	14.30	1,492
	16.2	85.71	56.37	23.57	63.44	21.99	19.67	1.75	13.82	1,505
1950	15.3	83.27	52.97	26.13	60.81	22.26	19.63	.50	13.99	1,597
	15.7	89.22	56.86	29.36	64.53	24.25	21.36	1.91	14.62	1,580
	16.3	94.56	58.19	29.86	72.54	29.09	25.59	2.75	17.19	1,612
	16.1	92.34	58.35	29.18	64.85	25.08	22.43	2.82	15.96	1,635
1951	13.6	97.42	62.34	33.11	65.96	26.66	23.74	1.46	16.13	1,591
	13.9	97.89	64.25	34.99	65.52	26.18	23.17	1.80	15.16	1,606
	14.4	97.79	64.33	32.96	66.67	26.42	22.68	2.19	14.98	1,620
	14.2	96.73	64.60	30.62	63.40	22.68	20.57	2.37	14.16	1,622
1952	15.1	95.97	61.49	31.23	59.91	21.58	18.62	1.94	14.85	1,629
	15.4	94.69	60.12	30.86	60.74	22.73	19.99	1.74	15.36	1,625
	16.0	92.59	59.24	27.93	65.84	24.59	21.40	2.78	14.16	1,633
	15.7	90.98	57.82	22.66	61.87	21.30	18.64	2.52	16.08	1,665

APPENDIX C (CONTINUED)

Year	Q_B[1]	P_{BR}[2]	P_{BW}[3]	P_{BF}[4]	P_{PR}[5]	P_{PW}[6]	P_{PF}[7]	M_1[8]	M_2[9]	Y[10]
1953	18.8	76.78	46.81	20.99	61.88	23.19	20.90	2.62	15.00	1,686
	19.2	71.61	41.39	19.72	69.03	26.81	24.44	2.97	15.06	1,690
	19.9	73.96	46.53	18.83	74.17	28.56	25.40	3.15	13.10	1,676
	19.7	73.88	45.54	16.80	67.27	25.50	23.51	2.78	13.91	1,666
1954	19.4	72.78	43.34	18.77	72.57	29.58	27.14	2.27	14.34	1,673
	19.9	72.76	43.13	19.79	73.50	30.03	26.15	2.47	13.85	1,674
	20.6	72.68	45.13	18.21	68.41	25.20	21.67	3.12	12.66	1,668
	20.2	74.60	48.18	17.88	62.70	22.18	19.40	2.77	12.17	1,689
1955	19.6	74.68	48.04	19.12	59.44	20.21	17.53	1.99	12.11	1,702
	20.3	72.72	43.59	19.09	59.61	21.44	18.23	2.41	13.57	1,749
	21.5	71.66	43.53	18.14	61.18	20.13	17.13	3.23	12.98	1,768
	20.6	70.30	40.37	16.41	54.81	16.75	13.26	3.14	14.69	1,787
1956	21.3	66.49	37.54	16.66	50.75	16.55	13.05	2.73	14.42	1,791
	21.5	66.52	38.20	17.77	55.05	19.18	16.31	2.68	13.54	1,810
	21.3	71.88	45.84	18.36	57.92	19.36	16.79	3.57	10.72	1,797
	21.3	73.75	45.73	16.27	56.25	18.68	16.24	3.29	14.67	1,807
1957	21.5	68.74	38.40	17.14	58.80	20.57	17.91	2.77	14.53	1,825
	20.8	71.41	41.38	19.33	60.86	21.31	18.46	2.87	13.62	1,833
	21.6	74.24	44.51	19.67	66.43	22.64	20.10	3.32	13.22	1,841
	20.7	73.84	43.94	19.40	59.80	20.17	17.49	2.62	13.89	1,816
1958	19.5	78.80	47.35	21.87	63.10	22.32	19.88	2.71	12.97	1,793
	19.8	82.22	47.56	23.83	65.74	23.86	21.17	2.19	14.79	1,788
	21.0	80.57	45.41	23.02	66.90	23.29	20.92	2.85	15.94	1,829
	20.2	80.28	45.21	23.11	61.65	20.61	17.94	2.45	15.65	1,837
1959	19.1	82.34	47.91	24.02	58.63	18.25	15.87	2.86	14.55	1,859
	20.0	82.41	48.26	25.16	57.51	18.22	15.25	2.72	14.20	1,893
	21.1	81.06	45.88	23.80	56.23	16.26	13.51	2.84	15.08	1,873
	20.2	80.25	44.43	21.48	52.59	14.89	11.99	2.86	16.37	1,879

APPENDIX C (CONTINUED)

Year	Q_B[1]	P_{BR}[2]	P_{BW}[3]	P_{BF}[4]	P_{PR}[5]	P_{PW}[6]	P_{PF}[7]	M_1[8]	M_2[9]	Y[10]
1960	20.8	79.37	45.39	22.17	51.12	15.88	13.42	3.06	14.01	1,881
	20.9	79.71	45.23	22.54	54.56	18.08	15.54	3.00	14.27	1,899
	22.4	78.10	41.94	20.76	57.36	18.61	16.06	3.17	15.73	1,896
	20.9	76.97	42.36	19.96	56.84	19.04	16.30	2.52	15.74	1,880
1961	20.9	78.63	44.20	21.47	57.36	19.30	16.81	2.84	15.36	1,867
	22.2	76.13	40.12	20.29	56.11	18.22	15.84	3.06	17.01	1,900
	22.7	73.66	38.69	20.09	57.57	18.92	16.75	2.81	15.99	1,914
	22.0	75.43	41.04	20.39	56.31	17.70	15.56	2.66	15.45	1,931
1962	22.0	76.91	43.03	21.47	55.25	17.64	15.75	2.81	14.61	1,940
	22.1	76.52	42.33	21.52	54.94	17.04	14.97	2.78	14.82	1,953
	22.9	78.52	44.86	21.88	58.85	18.86	16.83	2.83	14.65	1,956
	21.8	80.83	45.89	22.19	56.56	17.42	15.52	2.29	14.21	1,969
1963	22.4	79.64	41.08	20.63	54.38	15.92	14.02	3.01	18.28	1,976
	23.4	74.41	38.20	19.58	52.21	15.69	14.03	3.26	17.03	1,986
	24.4	75.07	39.48	20.33	55.65	17.29	15.60	2.99	15.85	1,990
	24.0	74.49	37.62	18.65	53.07	15.71	13.48	3.14	17.71	2,010
1964	24.1	71.96	35.81	18.17	51.62	15.40	13.49	3.45	17.11	2,053
	25.7	70.44	35.03	17.64	50.79	15.32	13.57	3.83	16.99	2,095
	25.4	72.48	38.86	18.83	53.46	16.99	15.12	3.49	15.01	2,113
	25.2	72.95	37.67	17.60	52.53	15.92	13.69	3.15	16.60	2,126
1965	24.1	72.18	36.91	17.94	52.25	16.72	15.02	3.12	16.48	2,141
	24.7	73.47	40.26	20.56	54.42	19.40	18.23	3.17	14.30	2,153
	25.5	76.66	40.86	21.39	63.31	22.40	21.32	3.22	16.41	2,196
	25.1	75.07	39.59	20.02	63.87	23.77	22.40	2.87	16.99	2,219

[1] Q_B = Per capita quarterly beef consumption, carcas in pounds.

[2] P_{BR} = Estimated average beef price at retail of choice grade cuts. Cents per pound deflated by CPI (1957-59=100).

[3] P_{BW} = Average beef price at wholesale. Carcas weight, choice steers 600-700 pounds. N.Y. market. Dollars per 100 pounds deflated by CPI (1957-59=100).

[4] P_{BF} = Slaughtered cattle price. Estimated average cost per 100 pounds of slaughter under Federal inspection. U.S., Dollars per 100 lbs. deflated by CPI (1957-59=100).

[5] P_{PR} = Estimated average composite price of pork sold at retail cuts. Cents per pound deflated by CPI (1957-59=100).

[6] P_{PW} = Average wholesale value of hog products derived from 100 pounds live weight, Chicago. Dollars per pound deflated by CPI (1957-59=100).

[7] P_{PF} = Estimated average cost per 100 pounds hogs slaughtered under Federal inspection. Dollars per 100 pounds deflated by CPI (1957-59=100).

[8] M_1 = Live to wholesale price spreads, live weight basis. Dollars per 100 pounds deflated by CPI (1957-59=100).

[9] M_2 = Wholewale to retail price spreads, carcas weight basis. Dollars per 100 pounds deflated by CPI (1957-59=100).

[10] Y = Per capita disposable personal income. Current dollars deflated by CPI (1957-59=100).

Sources: Prices and margins derived from Livestock and Meat Statistics, U.S.D.A. Agricultural Marketing Service
Income: Economics Indicators. Prepared for the Joint Economic Committee by the Council of Economic Advisers. U. S. Government.
Quantity: U. S. Food Consumption. U.S.D.A.

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