Beef Demand Determinants

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Executive Summary

- Twenty years of declining demand has plagued the beef industry. Essential to designing long run strategies to reverse declining beef demand is having a better understanding of beef demand determinants. This study was designed to determine the major factors causing beef demand to shift over time.

- Over 1982 to 1998 inflation-adjusted beef prices declined by 32% while per capita beef consumption declined by nearly 10 lbs. per capita (from 77 lbs. to 68 lbs.). The fact that inflation-adjusted prices collapsed at the same time consumption was declining provides strong evidence that beef demand declined precipitously during this period. Recognizing the magnitude of beef demand decline is important, but critical to improving beef demand is quantification of individual demand drivers over time.

- A meat demand system was estimated using quarterly time series data over the 1982 to 1998 period. The system included factors accounting for prices of competing meats and total expenditures, changing consumer demographics, food safety problems, health information, and seasonality. The impacts of individual demand determinants on beef demand were calculated each year from 1992 through 1998 in-sample, and 1999 out-of-sample.

- Beef demand is inelastic with an own-price elasticity of –0.61. This means that, on average, beef quantity demanded declines 0.61% given a one percent increase in beef prices. Pork and poultry are both weak substitutes for beef with cross price elasticities of 0.04 and 0.02, respectively. Together these elasticity estimates indicate relative prices do matter, however, per capita beef consumption is not highly responsive to changes in pork and poultry prices. Beef expenditures represent a progressively smaller proportion of total consumer expenditures suggesting beef demand will become even more inelastic in the future. This means quality (especially tenderness) of high-valued beef table cuts will become more important in the future.

- Beef demand is highly responsive to changes in consumer disposable income, particularly the amount of income consumers choose to spend. Beef demand increases 0.90% for a 1% increase in total per capita expenditures. Consumer disposable income has increased over time and expenditures as a percentage of disposable income have increased from around 90% in the early 1980s to near 98% in 1999. Beef demand has benefited considerably from increasing consumer expenditures, but if consumers choose to increase savings in the future (in lieu of consumption) it will have a negative impact on beef demand.

- Beef demand declines when beef food safety recalls occur. For example, in 1993 beef recalls caused a 2.90% decline in beef demand. It is imperative the beef industry offer safe products consumers have confidence in. As a result, industry efforts to ensure that beef products are safe are important.

Executive Summary (continued)

- Health information linking cholesterol and heart disease weakened beef demand by about 0.60% annually from 1982 to 1999. The industry should continue efforts to provide balanced health information to consumers via consumer, nutritionist, and health advisor education. In addition, continued support of research to better understand these linkages and how the industry can address them will also provide long-run benefits to the industry.

- Increasing female labor force participation has had a strong negative impact on beef demand and has benefited poultry demand. Beef demand has declined an average of 1.3% annually over the 1992-99 period as a result of increasing female labor force participation. To the extent that female labor force participation provides a measure of consumer demand for product convenience, this means beef demand has declined in part because of a failure to offer consumers high quality, convenient, easy-to-prepare beef products. The beef industry needs to continue investing in the development of new products that reduce preparation time, without sacrificing quality, to attract today's time-constrained consumers.

- Meat demand is dynamic. Identification of demand determinants as they arise can only be done via rigorous modeling efforts. As a result, annual demand model updates that provide industry leadership with an ongoing assessment of factors affecting the demand for beef could provide valuable information to the industry.

Introduction

Beef demand declined every year from the late 1970s through the late 1990s. One measure of the demand decline, a beef demand index calculated by Purcell (1998), indicates beef demand fell by almost 50% from 1980 to 1998. In an attempt to halt declining demand, generic beef promotion and consumer information programs were introduced by beef producers in the mid-1980s. Moreover, beef producers' "war on fat", launched in 1990, and the 1991 and 1995 beef quality audits were motivated by efforts to "...improve the quality, consistency, competitiveness and market-share of beef" (Smith et al. 1995, p. 15).

To efficiently allocate limited producer resources among programs intended to stimulate beef demand requires an understanding of factors that shift beef demand over time. In particular, careful quantification of various demand shifters over time is essential to making informed decisions. If declining beef demand is not properly attributed to its primary causes, producers' resources may be expended on programs that have little or no positive impact on beef demand.

The purpose of this study is to develop a demand model that quantifies major beef demand determinants over time. In particular, the model is designed to facilitate annual assessments regarding which factors caused beef demand to shift, the direction of the shift caused by these factors, and the relative magnitude of the shifts caused by each factor. Following this approach, aggregate beef demand shifts over time are allocated to the various factors contributing to the demand change.

Proper development of a beef demand-monitoring model required several conditions be met. First, a model capable of detecting periodic changes in demand and attributing them to identifiable economic, demographic, and/or consumer lifestyle trends was needed. Second, to make future updates feasible, the model had to rely on publicly available data. Third, the research had to be conceptually sound, conducted using rigorous scientific methods, and well accepted by professional agricultural economists. To ensure this outcome, the study was peer reviewed by three prominent meat demand economists: Dr. Gary Brester, Montana State University; Dr. Oral Capps, Jr., Texas A&M University; and Dr. Nicholas Piggott, North Carolina State University. The reviewers provided in-depth comments and their suggestions were incorporated into the final version of this report.

Beef Demand Background

To reverse the demand trend it is critical to understand what demand is, what it has done over time, and what the major demand determinants are. This section of the report covers the first two components and a subsequent section addresses the last component.

Defining Beef Demand

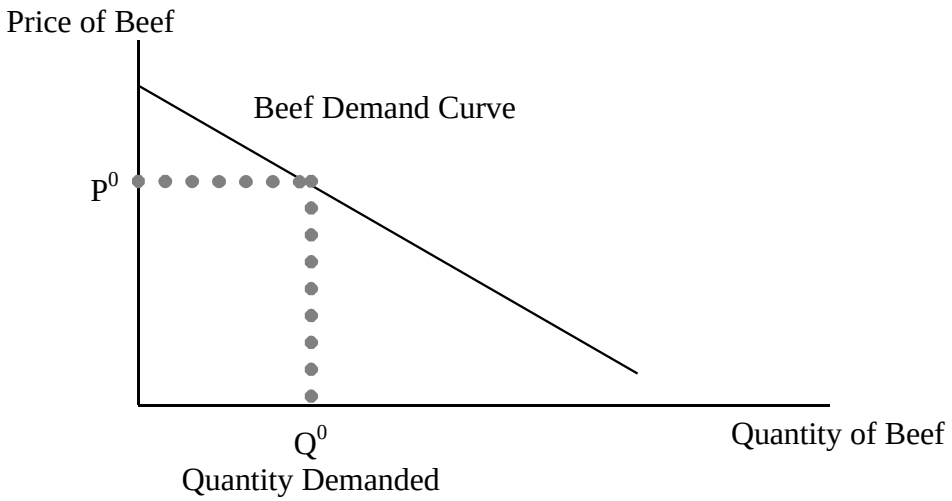
One challenge facing the beef industry is a poor understanding of beef demand and its determinants. Part of the problem is confusion over terminology. Economists

differentiate between two related, but distinctly different, terms; 1) quantity demanded and 2) demand. A meaningful discussion of beef demand requires a clear distinction between these two terms.

Quantity demanded refers specifically to the quantity of beef a consumer will purchase at a given beef price, holding all other factors constant. On the other hand, demand, sometimes referred to as a demand curve, is a schedule of beef quantities consumers will purchase over a range of beef prices. Figure 1 depicts a stylized beef demand curve.

The graph of the beef demand schedule in Figure 1 depicts a typical downward sloping demand curve. The graph illustrates that, at lower beef prices, consumers are willing and able to consume larger quantities of beef and, at higher prices, consumers are willing and able to consume smaller quantities of beef. Note that on the graph at price P^0 the quantity demanded by consumers is Q^0. This particular quantity (Q^0) is referred to as the *quantity demanded* by consumers at price P^0. At prices above P^0, the quantity demanded will be smaller than Q^0 and at prices below P^0 the quantity demanded will be larger than Q^0. Finally, note that as quantity demanded changes, beef price changes, but it does so by moving along the demand curve in Figure 1. Examined in this way, it is clear that changes in quantity demanded are not tantamount to shifts in beef demand since they merely result in movement along an existing demand curve. This is why changes in per capita consumption are not in and of themselves indicative of a change in demand.

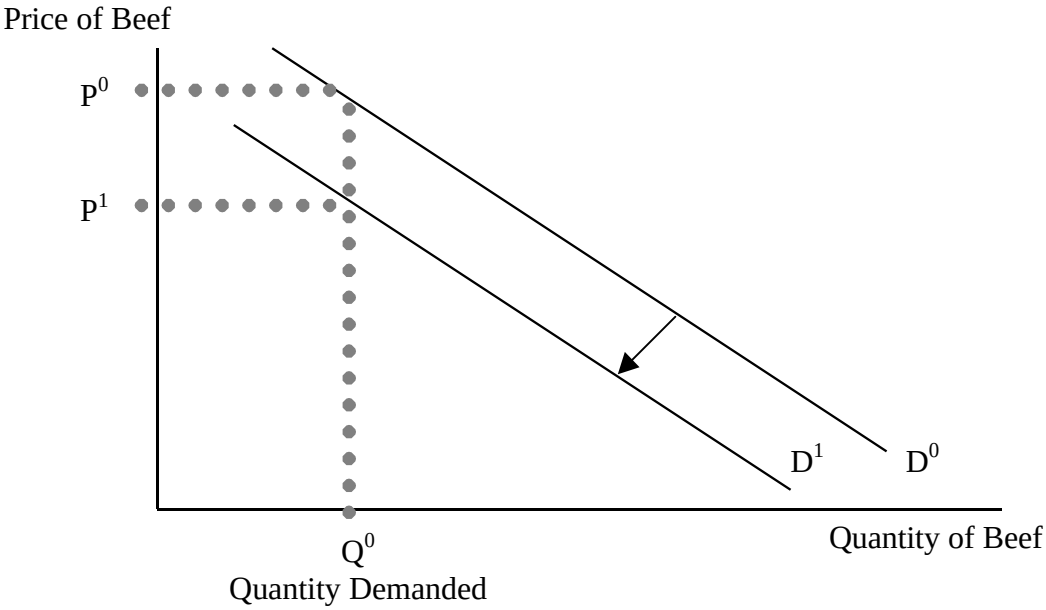
Figure 1. Stylized Beef Demand Curve.



What then do economists mean when they refer to a shift in demand? A shift in beef demand occurs when the entire beef demand curve shifts up (demand increase) or down (demand decrease). Figure 2 depicts a downward shift of the beef demand curve from the curve labeled D^0 to the curve labeled D^1. Note that, after the demand curve has shifted down from D^0 to D^1, beef price, for any given quantity demanded by consumers, will be lower than it would have been if demand curve D^0 was operative. Changes in beef price or the quantity of beef do not cause the beef demand curve to shift. Rather, changes in

other exogenous factors, such as changes in prices of competing meats (e.g., pork or poultry), common demographics (e.g., income, age distribution, etc.), or health or food safety concerns cause the beef demand curve to shift.

Figure 2. Beef Demand Shift.



On an annual basis, the amount of beef consumed is essentially the amount produced, aside from relatively small changes over time in beef cold storage stocks and changes in net exports. Since exports and imports each represent a small percentage of total production and somewhat offset each other (i.e., net imports are a small percentage of total consumption), annual domestic beef consumption closely follows annual domestic beef production.[1] In the context of the previous discussion of beef demand, this situation essentially means the quantity of beef moving through marketing channels is, in the short run, predetermined. Thus, we can view Q^0 in Figure 2 as given during a particular time period, and the intersection of that quantity with the beef demand curve will determine beef's market clearing price. In the short run, beef quantity is fixed, meaning the supply of beef is perfectly inelastic (that is the supply of beef is the same at all price levels). This means that, in the short run, beef price is the adjustment mechanism. When beef supplies are large, retailers reduce price to encourage product movement (i.e., increase the quantity demanded) which causes reductions in wholesale and farm-level beef prices. Conversely, when supplies are small, retailers raise prices which causes consumers to reduce the quantity demanded.

[1]As a percentage of U.S. beef production, imports (including live cattle) have averaged roughly 14% and exports roughly 7-8%, on a volume basis, over the past several years (Livestock Marketing Information Center and Brester and Marsh 1999).

Because there is considerable confusion surrounding demand, it is useful to stipulate what beef demand is not. *Beef demand is not per capita beef consumption.* Per capita consumption *is* beef production (net of changes in cold storage, imports, and exports) divided by population. Observing per capita consumption over time without consideration of price provides little information regarding beef demand. *Beef demand is not beef's relative share of total meat consumption.* Again, this share concept simply reflects production of beef relative to production of competing meats. Relative, or absolute, production and consumption are not demand because these variables alone do not include information regarding prices. *Finally, beef demand is not the share of consumer income spent on beef.* Consumer income level affects beef demand, but changes in the share of consumer income spent on beef does not provide a measure of whether beef demand is increasing or decreasing. This is because changes in income cause changes in the share of consumer income spent on beef, even if beef demand remains unchanged. See Purcell (1998a) for a detailed discussion defining beef demand.

Beef demand *is* a schedule of the quantities of beef consumers are willing and able to consume at various price levels. The location of the beef demand curve (as depicted in Figure 2) at a point in time is dependent on what are referred to as beef demand determinants. Based upon consumer demand theory, beef demand determinants are competing meat product prices, consumer income, demographics, and consumer knowledge and preferences. Changes in these broadly defined beef demand determinants lead to shifts in the beef demand curve. When beef demand increases (i.e., shifts up), say as a result of an increase in the price of poultry that causes consumers to substitute beef for poultry, the result is higher beef prices at any level of beef consumption (production) than prior to the demand shift. Conversely, when beef demand decreases (i.e., shifts down) beef prices are lower at any beef consumption (production) level than prior to the demand shift. Since many beef demand determinants, as well as beef production, change at the same time, it is impossible to accurately assign relative demand shifts to individual demand determinants through casual observation of trends and beef demand shifts.

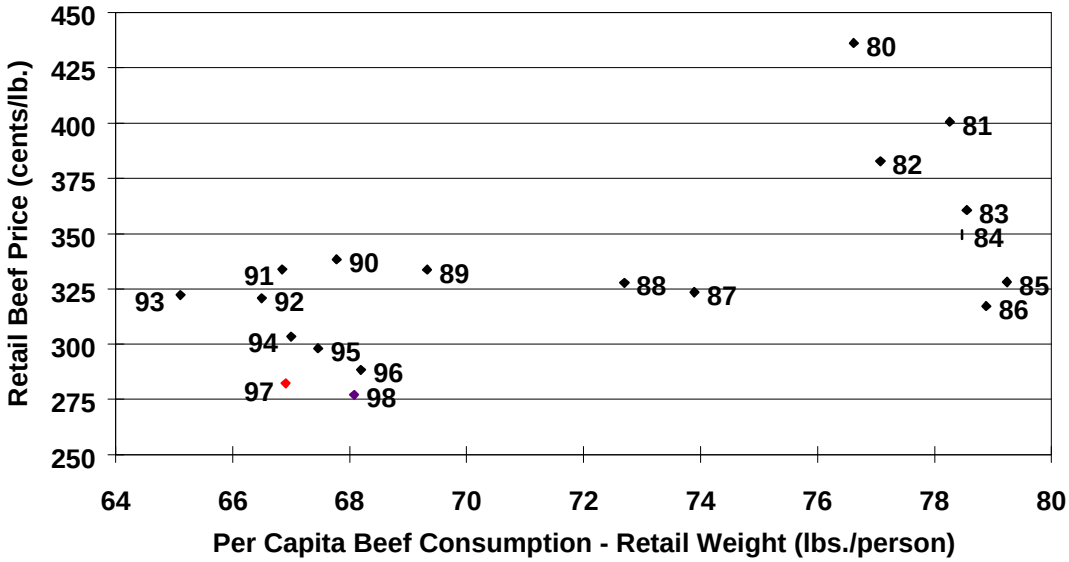
To quantify the impact changes in various beef demand determinants have had on beef demand, a meat demand model, such as the model reported later in this paper, must be employed. However, important to understand is that even when a comprehensive demand model is estimated, it is often difficult to accurately separate out the individual effects of each possible demand determinant. There are several reasons it is difficult to separate out all individual demand determinants. For example, if two demand factors follow each other closely over time (like female labor force participation and consumer health information, as discussed later), the separate causal effects can be difficult, if not impossible, to sort out. Other challenges to separating individual demand determinants include data measurement errors, unavailability of data, or modeling limitations.

Demand Trends

In order to identify reasons for its decline, recent beef demand trends merit review. Figure 3 illustrates beef price-quantity relationships (i.e., points on various demand curves) from 1980-98. From 1980 to 1986 the amount of beef offered for consumption

increased slightly over 2 pounds per person. However, inflation-adjusted retail beef price had to decline 27% to encourage consumers to consume this additional 2 pounds. This large decline in retail price also was reflected in a 35% decrease in inflation-adjusted fed steer prices over this same seven-year time span.

Figure 3. Annual Deflated Beef Price - Quantity Relationships, 1980-1998



Source: USDA & Commerce Dept.
Price Deflated by GDP Implicit Price Deflator 1998=100

The large decline in fed cattle price led to a decline in calf price that prompted considerable liquidation in the beef-cow herd. The liquidation started gradually in 1983 and noticeable beef production declines occurred by 1987.[2] From 1986 to 1993, beef consumption per person fell by 18% (Figure 3). If beef demand had been stable during this period, the huge decline in per capita beef supplies would have pushed retail beef prices substantially higher (i.e., about 25% higher based on typical estimated beef demand flexibilities[3]). Instead, inflation-adjusted retail beef price increased a paltry 1.5% confirming that beef demand declined (i.e., the beef demand curve shifted down) substantially. Per capita consumption increased by more than 2 lbs. per person since 1993, but beef demand continued to decline as inflation-adjusted beef prices were still declining more than expected, if the beef demand curve had been stable. Since it is

[2] From 1982 to 1986 the U.S. beef cow herd size declined by 14% and liquidation continued until 1990 when the size of the cow herd was 17% smaller than in 1982 (Livestock Marketing Information Center).

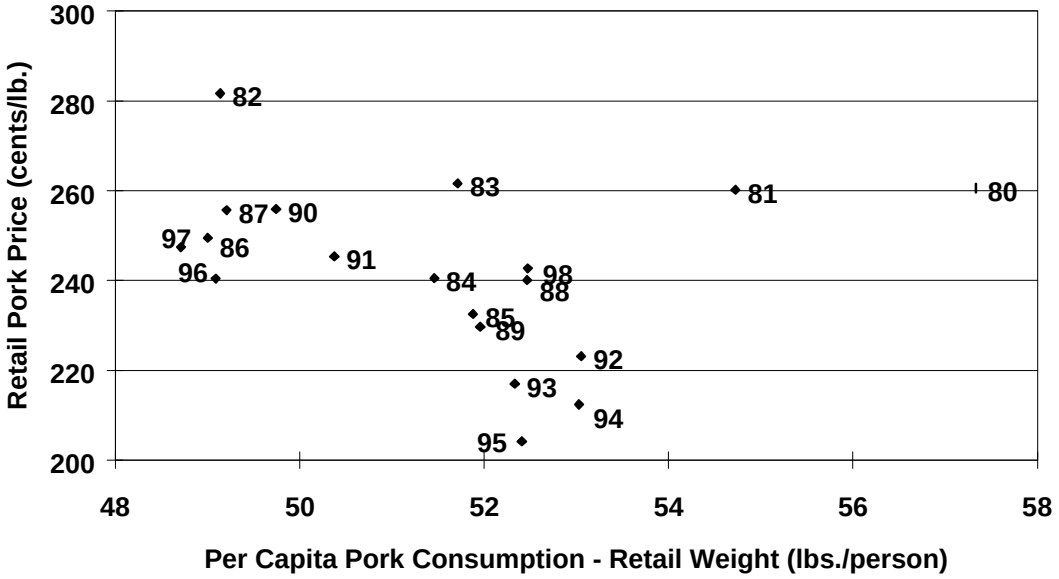
[3] Demand flexibilities are the percentage change in price for a one percent change in quantity demanded. Beef demand flexibilities reported in the literature are about –1.5 (Dahlgran 1987; and Eales and Unnevehr 1993).

apparent beef demand was declining throughout most of the 1980s and 1990s, the question is what induced these large downward shifts in beef demand?

Some observers have concluded that shifts in relative prices of beef and competing meat products were responsible for the beef demand decline. Although beef prices increased relative to competing meat product prices, especially chicken and turkey, during the 1960s and 1970s, Choice retail beef prices actually fell relative to pork and chicken prices in the 1980s and 1990s. For example, the beef/pork retail price ratio was 1.32 in 1990, but declined to 1.14 in 1998. Similarly, the beef/chicken retail price ratio was 3.13 in 1990, but fell to 2.66 in 1998. The inference is that other factors, such as food safety, product convenience, nutritional and/or health concerns, and consumer demographic changes must have impacted beef demand over the last two decades. The meat demand model presented later in this report provides empirical evidence regarding which of these factors had a significant impact on meat demand and the relative magnitudes of their impact.

Because competing meat markets affect beef demand, a brief review of the demand situation for primary competing meats, pork and chicken, is in order. Relative to beef, pork demand has been more stable. Although some decline in demand has occurred, pork demand has not exhibited continual declines over time (Figure 4). For example, relative to 1995, inflation-adjusted retail prices and quantities consumed during 1998 were both higher. This result indicates retail pork demand was stronger in 1998 than in 1995. Furthermore, pork demand in 1998 was nearly the same as in 1988 (although it varied from year to year), a sharp contrast to beef demand's 22% decline over the same period.

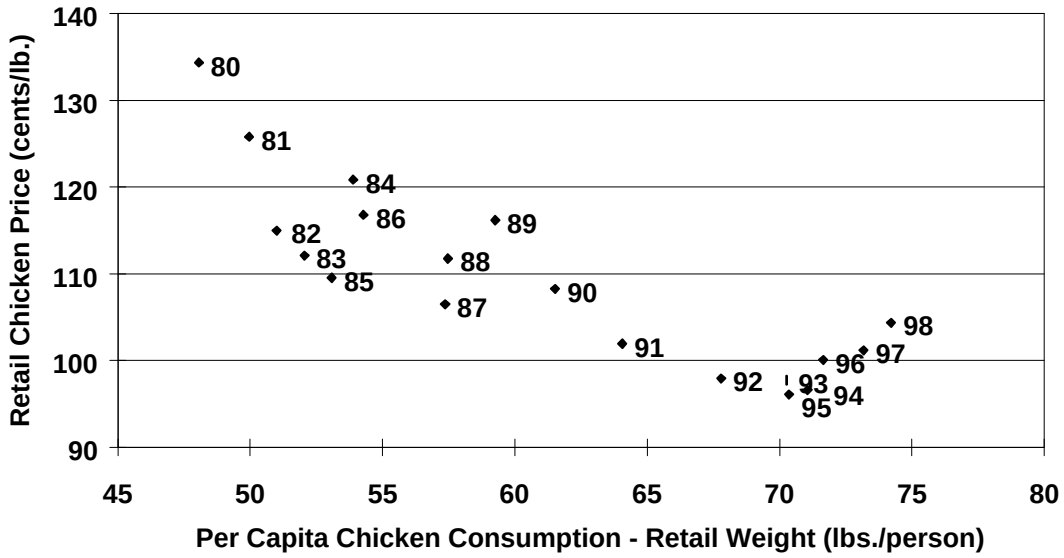
Figure 4. Annual Deflated Pork Price - Quantity Relationships, 1980-1998



Source: USDA & Commerce Dept.
Price Deflated by GDP Implicit Price Deflator 1998=100

Poultry has enjoyed huge increases in consumption and reductions in real prices from 1980 to 1998 (see Figure 5 for chicken price-quantity relationships). From the graph alone, it is not possible to make a strong inference about chicken demand over time because real prices declined as per capita consumption increased. However, poultry demand curves are thought to be steeply sloped since own-price demand elasticity estimates for chicken are generally –0.40 or smaller in absolute value (Brester and Schroeder, 1995; Brester and Wohlgenant, 1991; and Kinnucan et al., 1997). Given the steep slope of chicken demand curves, the best explanation for the price-quantity data plotted in Figure 5 is that chicken demand was increasing progressively (i.e., the demand curve was shifting out to the right) over time.

Figure 5. Annual Deflated Chicken Price - Quantity Relationships, 1980-1998

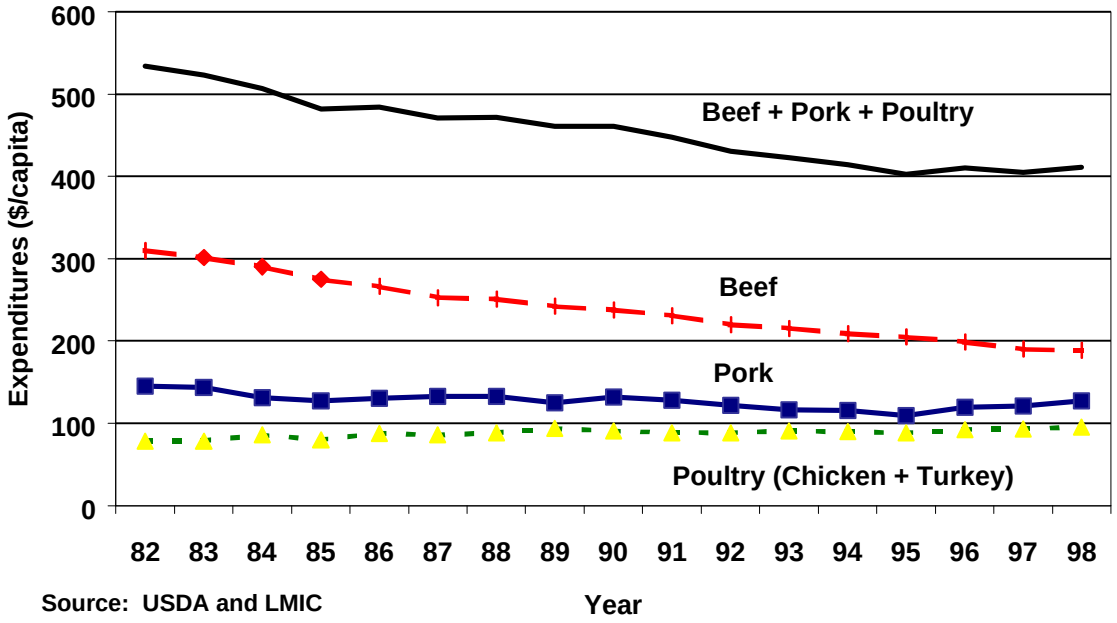


Source: USDA & Commerce Dept.
Price Deflated by GDP Implicit Price Deflator 1998=100

Expenditure Trends

Per capita expenditures on meat consumption is not an indicator of demand. However, expenditures provide information on how consumers are allocating their income among competing meats. Figure 6 illustrates the trend in per capita meat expenditures over the 1982-98 period. Total inflation-adjusted meat (beef + pork + chicken + turkey) expenditures declined by about $100/capita or 20% from 1982 to 1998. The $100/capita decline in meat expenditures was virtually all attributable to declining beef expenditures as pork and poultry expenditures were nearly constant. This finding indicates consumers allocated fewer total dollars to meat expenditures over time, primarily because of reduced expenditures on beef.

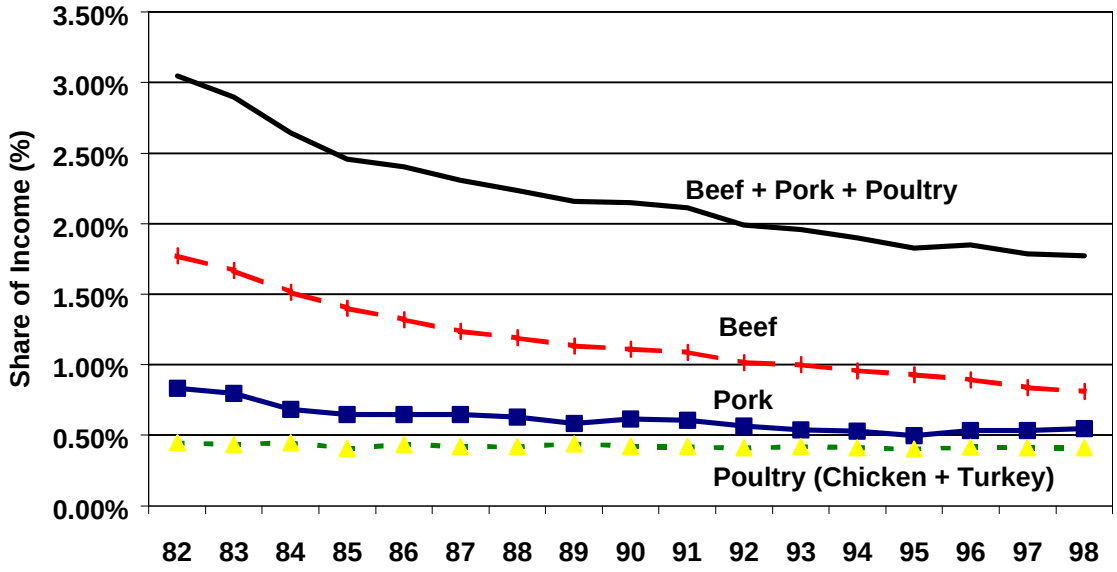
Figure 6. Annual Inflation-Adjusted Per Capita Beef, Pork, and Poultry Expenditures, 1982-1998 (1998 Dollars).



Source: USDA and LMIC

How consumers have allocated per capita disposable income among competing meats is closely related to the expenditure share allocation. Figure 7 illustrates the shares of consumer income allotted among beef, pork, and poultry from 1982 to 1998. In 1982 consumers spent 3.05% of their disposable income on meat with 1.77% going to beef, 0.83% to pork, and 0.45% to poultry. By 1998, consumers only allocated 1.77% of their income to total meat expenditures (i.e., the amount they were spending on beef alone in 1982) and the share of income spent on beef and pork declined to 0.81% and 0.55% respectively. Meanwhile, the share of income spent on poultry declined less, falling just 0.04% to 0.41%. Consumer income in 1998 dollars has increased from approximately $17,500/capita in 1982 to $23,200/capita in 1998. Thus, although consumer disposable income rose, consumers spent proportionately less of their income on meat products each year, even though they consumed more total meat per person. Total meat consumption increased, even with reduced expenditure levels, because the inflation-adjusted price of meat declined and consumers substituted consumption of more expensive beef for less expensive poultry.

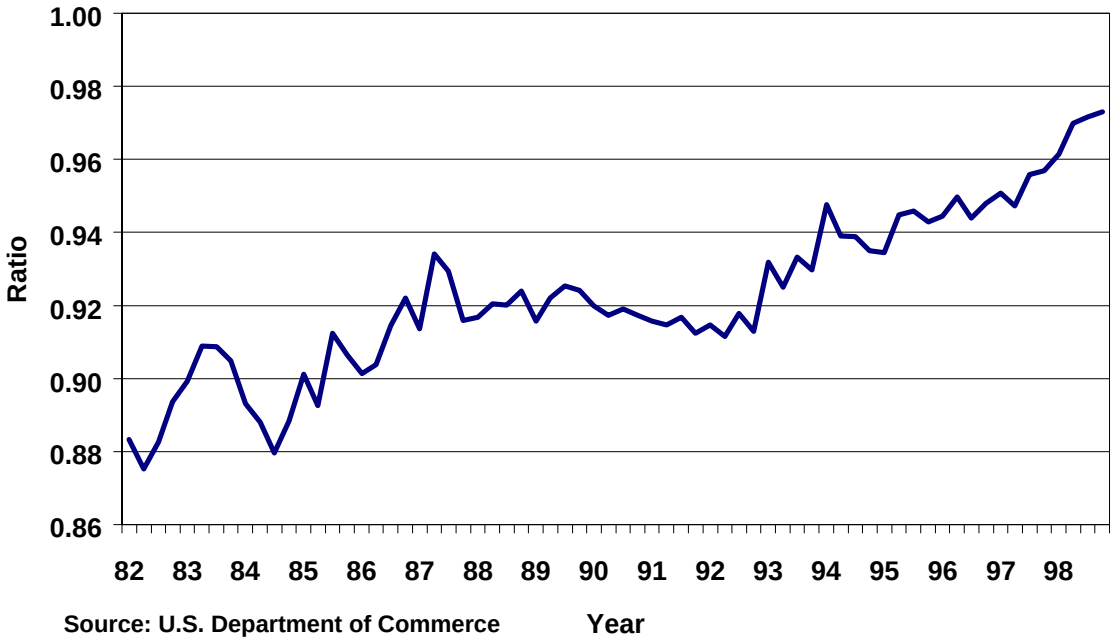
Figure 7. Beef, Pork, and Poultry Expenditures as a Percentage of Disposable Personal Income, 1982-1998.



Source: USDA and LMIC

At the same time meat expenditures were declining relative to disposable income, total consumer expenditures as a percentage of disposable income were increasing (Figure 8). During the early 1980s consumers typically spent around 90% of their disposable income on goods and services. This trended upward to about 92% during the early 1990s. By the late 1990s consumers were spending more than 95% of their disposable personal income. Had consumers not been spending an increasing proportion of their income over the time period, it is likely meat expenditure as a percentage of disposable income (Figure 7) would have declined even more rapidly than it did.

Figure 8. Ratio of Per Capita Consumption Expenditures to Disposable Personal Income, Quarterly 1982-1998.



Source: U.S. Department of Commerce

Background and Literature Review

It has long been understood that meat prices are primary determinants of per capita beef consumption. This means quantity of beef demanded is typically modeled as a function of beef price, prices of competing meats, and other potential demand shifters, such as total meat expenditures. However, many meat demand studies have concluded that the impacts of competing meat prices on beef consumption are not stable (e.g., Eales and Unnevehr, 1988; Moschini and Meilke, 1989; McGuirk *et al.*, 1995). This finding suggests meat consumption patterns are determined by other factors in addition to relative prices and total meat expenditures.

As a result, some of the more recent meat demand literature has focused on identifying other factors that have affected meat demand and finding ways to explicitly incorporate these factors into meat demand models. For example, McGuirk *et al.* (1995) found both health information and a changing labor force contributed to structural change in meat

demand from 1960 to 1988. Kinnucan *et al*. (1998) examined the effects of health information and generic advertising on meat demand and concluded health information had a relatively large impact on meat demand, whereas generic advertising impacts were small and unstable. Capps, Moen, and Branson (1988) also concluded consumer attitudes toward fat affected demand for lean meat products. LaFrance (1999) examined food consumption from 1918-1994 and incorporated age-distribution, ethnic background, and habit formation into his analysis, in addition to the traditional meat demand determinants. Over this long time frame, LaFrance concluded ethnicity and age distribution both affected beef demand. Capps, Tedford, and Havlicek (1985) found that food product convenience attributes affected consumer demand. In particular convenient food products had more price responsive demand curves than less convenient foods.

A recent example of a factor that could be affecting meat demand is the emergence of concerns about food borne illnesses. In the United States, numerous food products have transmitted food borne illnesses to consumers via a myriad of known and unknown food borne pathogens (Centers for Disease Control and Prevention). In meats, common food borne diseases include *Listeria monocytogenes*, *Escherichia coli* (*E coli* O157:H7), and *Salmonella*. Recent research by Flake and Patterson (1999) examined the impact of health information and food safety on beef demand. A food safety information index was constructed by counting the number of Associated Press articles filed on BSE, and *E. coli* and salmonellosis contamination in beef. Their findings suggest food safety concerns have had a modest impact on meat demand.

A summary of beef demand elasticity estimates for selected studies estimated using time series data is reported in Table 1. Beef own-price demand elasticity estimates ranged from –0.28 to –0.85 with most estimates falling between –0.40 and –0.70. This indicates per capita beef consumption changes less, proportionally, than retail price (i.e., beef demand is inelastic) as price changes. Pork and poultry tend to be substitutes for beef with pork appearing to be a stronger substitute than poultry in most studies. Fish has been estimated to be a weak substitute for beef. Beef income or expenditure elasticity estimates have all been positive, but vary in magnitude. Differences in the magnitudes of the estimated elasticities are partially attributable to some estimates being expenditure elasticities, measuring how beef demand changes in response to a change in meat expenditure, whereas other estimates measure beef demand changes in response to disposable income changes. Beef demand expenditure elasticities are generally larger than income elasticities because beef demand is more responsive to changes in meat expenditure than it is to changes in consumer disposable income.

Examined as a group, recent meat demand research indicates conclusively that factors in addition to meat prices and consumer expenditures on meats must be employed as explanatory variables in meat demand models. Factors to consider including in meat demand models are variables measuring health information, product convenience, food safety, product quality attributes, product promotion, and changes in consumer demographics. The challenge to a comprehensive beef demand modeling effort is to incorporate as many of these factors as feasible, given data and estimation technique limitations.

Table 1. Summary of Beef Compensated Demand Elasticity Estimates from Selected Studies.

Study	Years	Frequency	Own Price	Pork Price	Poultry Price	Fish Price	Other Food	Income or Expenditure	Generic Advertising	Health
Brester & Schroeder, 1995	1970-93	Quarterly	-0.56	0.10	0.05		0.41	0.13[a]	0.006	
Capps & Schmitz, 1991	1966-88	Annual	-0.36	0.24	0.10	0.02		0.90[b]		
Chavas, 1983	1950-70	Annual	-0.62	0.36	0.08			0.18[c]		
Coulibaly & Brorsen, 1999	1970-93	Quarterly	-0.25	0.34	-0.08			0.40[b]	0.00003	
Dahlgran, 1987	1950-85	Annual	-0.66	0.14	0.04		-0.00	0.44[a]		
Eales et al., 1998	1980-96	Quarterly	-0.28	0.24	0.04			1.21[a]		
Eales & Unnevehr, 1988	1965-85	Annual	-0.57	0.17	0.05		-0.04	0.34[d]		
Eales & Unnevehr, 1993	1962-89	Annual	-0.85	-0.05	0.07		0.64	0.79[a]		
Kinnucan et al., 1997	1976-93	Quarterly	-0.42	0.29	0.10	0.03		1.00[b]	0.001	-0.68
Piggott, 1997	1979-95	Quarterly	-0.27	0.21	0.07			1.23[b]	0.004	

[a] Total expenditure elasticity.
[b] Meat expenditure elasticity.
[c] Disposable income elasticity.
[d] Food expenditure elasticity.

Demand Model

Quantifying the primary factors causing shifts in meat demand requires development of an economic model. The principal concerns in model selection were that the model was both theoretically sound and suitable for the data and problem being evaluated. The demand model is a system of equations that estimates beef, pork, and poultry demand together and accounts for their interrelationships. The demand model employed in this study has four equations (beef, pork, poultry, and all other goods). The model used is what is referred to as a Linear Almost Ideal Demand System (LAIDS). Details of the demand model employed are provided in the Appendix.

The Beef Demand Study Group (1998) identified five specific beef demand drivers they felt were important beef demand determinants. These factors in unranked order included: "1. Food Safety, 2. Palatability, 3. Health & Nutrition, 4. Consumer Friendly Products – convenience, and 5. Cost/Price/Perceived Value – relative to price of competitive meats" (p. 2). Demand determinants identified by the Beef Demand Study Group, plus those identified in previous research, were employed in the meat demand modeling effort reported here.

In particular, we explicitly included variables in the modeling effort to account for food safety, product convenience, health concerns, consumer demographic changes, meat product prices, and meat expenditures. No explicit measure of product palatability is included in the models because historical time series of this measure were not available. Perhaps more importantly, no direct measure of new product (beef or competing meats) development is included in the model because time series data summarizing product introductions or sales were not available. As a result, any effect these factors had on meat demand are partially reflected in other demand factors included in the model or are part of the unexplained demand variation over time. Advertising expenditures on meat were not included in the model as previous research indicates the impacts have been quite small and often not statistically significant (Brester and Schroeder, 1995; Kinnucan *et al.*, 1997; and Coulibaly and Brorsen, 1999). Finally, seasonality of meat demand was incorporated in the model through the use of quarterly demand shift (binary) variables.

In addition to prices of competing meats and meat expenditures, several demographic variables were specified as potential demand shifters in the initial model. Mean age of the population was included to account for potential demand shifts attributable to changing demand for meat products by an aging population. Race variables, measured by the percentage of the population categorized as caucasian, black, and other, were included in the model to capture the effect of the changing population racial structure over time (see, for example, LaFrance 1999; Capps and Schmitz 1991). Finally, in an attempt to capture the impact of food eaten away from home, demand for product preparation convenience, and other related lifestyle changes, a variable measuring changes in the percentage of females in the labor force was included in the model (see, for example, McGuirk *et al*.1995).

Given the relatively short time period of this study (1982-1998 as discussed further in the Data section), the mean age of the population and race distribution variables were relatively unchanged or highly collinear (correlated) with the percentage of females in the labor force. Therefore, in the final model, the percentage of females in the labor force was employed as a proxy variable for changing demographic trends over the study period. This variable was expected to capture much of the changing demand for product convenience over time.

Data

The meat demand model was estimated using quarterly data from 1982-1998. The data set was restricted to this period, for several reasons. First, the intent was to estimate a model covering the period when most observers felt beef demand had experienced a sharp decline and to incorporate variables in the model that explained most of the observed demand shifts. A longer time series would have been useful to test whether or not structural change had occurred in meat demand, but this was not the project's objective. Furthermore, many factors associated with changing consumer preferences are not easily measured with available time series data making structural changes in the model more probable. Thus, extra care may be needed when making projections using consumer demand models estimated with long historical time series that have not accounted for changes in consumer preferences. However, it was important to use a time series of sufficient length to ensure the resulting model estimates had desirable statistical properties. Given that most analysts believe the decline in beef demand originated around 1980, data was originally collected from 1980 forward. However, the Food Safety Inspection Service (FSIS) data for food safety recall events was only available starting in 1982. Therefore, the model estimation period included data from the first quarter of 1982 through the fourth quarter of 1998.

The beef, pork, chicken, and turkey quantity variables used in the model represent quarterly per capita disappearance expressed in retail weight (pounds). The beef, pork, and poultry price variables are estimates of quarterly average retail prices (cents per pound). Quantity and price series are reported by the Livestock Marketing Information Center (LMIC) and the United States Department of Agriculture - Economic Research Service (USDA-ERS). Following Brester and Schroeder (1995, footnote 5) the price index of other consumption goods is calculated as a weighted combination of the consumer price index less the price indexes for beef, pork, and poultry. Personal consumption expenditure and its associated implicit price deflator, which are used to calculate per capita real consumption expenditures, come from the National Accounts data published by the United States Department of Commerce - Bureau of Economic Analysis. The Consumer Price Index for all urban consumers (CPI), used to adjust for inflation over time, represents the U.S. city average price of all items, as reported by the United States Department of Commerce - Bureau of Labor Statistics (BLS).

The health safety and demographic data used as demand shifters in the demand system came from several sources. The health index follows the Brown and Schrader (1990)

approach using cholesterol information (also used by Capps and Schmitz 1991; and Kinnucan *et al*. 1997), and is updated through 1998. The health index is the cumulative sum of articles published in English medical journals supporting the linkage between cholesterol and heart disease, less the number of articles refuting the linkage.

Demographic variables considered in the demand estimation were the percentage of females in the civilian labor force reported by the BLS; the proportion of caucasian, black, and other races reported by the Population Estimates Program, Population Division, U.S. Census Bureau; and the mean age of the population derived from the Population Estimates Program, Population Division, U.S. Census Bureau. As discussed previously, of these demographic factors only the female-labor-force participation variable was incorporated in the final demand model.

Food safety is represented by incidences of recall by meat type publicly reported by the United States Department of Agriculture Food Safety Inspection Service (FSIS) from 1982-1998. Recall incidences were aggregated into quarterly estimates, creating three separate food safety indexes for beef, pork, and poultry. Each index accounts for an assortment of pathogens (e.g., *Listeria monocytogenes*, *Escherichia coli* (*E. coli*), and *Salmonella* as well as other contaminants) identified at the time of recall.

Summary statistics of data used in estimation of the beef demand model are contained in Table 2. Per capita beef consumption was the largest of the three meat groups, averaging 17.8 lbs./capita/quarter, with poultry second, averaging 15.6 lbs./capita/quarter, followed by pork with an average consumption of 12.8 lbs./capita/quarter. Per capita consumption trends are illustrated in Figure 9. The graph makes it apparent that per capita beef consumption declined over time whereas per capita poultry consumption increased steadily. Per capita beef consumption reached its 1982-98 peak during the third quarter of 1985 at 20.8 lbs./capita. Beef consumption trended downward to a low of 15.9 lbs. in fourth quarter 1994 and first quarter 1995.

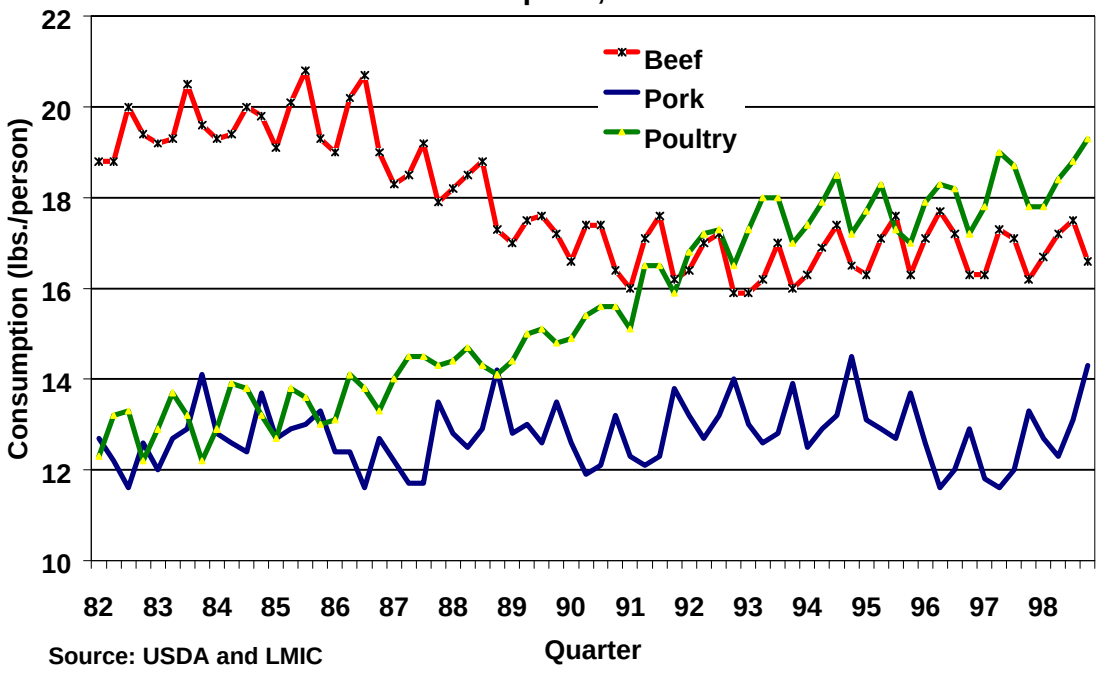
Poultry consumption trends were markedly different from those identified for beef. Poultry consumption reached its 1982-98 minimum of 12.2 lbs. in the fourth quarters of 1982 and 1983 and climbed to its maximum of 19.3 lbs. in fourth quarter 1998. Pork consumption was more stable than either beef or poultry consumption, generally oscillating between 12 and 14 lbs./capita/quarter over the 17-year period.

Table 2. Summary Statistics of Quarterly Data used to Estimate Beef Demand, 1982-98.

Variable	Average	Std. Dev.	Minimum	Maximum
Beef Consumption (lbs./capita)	17.8	1.38	15.9	20.8
Pork Consumption (lbs./capita)	12.8	0.69	11.6	14.5
Poultry Consumption (lbs./capita)	15.6	2.07	12.2	19.3
Retail Beef Price (cents/lb.)[a]	335.36	33.68	275.40	413.09
Retail Pork Price (cents/lb.)[a]	249.15	23.42	203.73	311.56
Retail Poultry Price (cents/lb.)[a]	110.77	10.68	96.72	136.45
Beef Expenditure Share (%)[b]	52.5	3.9	43.2	59.2
Pork Expenditure Share (%)[b]	28.1	1.6	25.1	32.0
Poultry Expenditure Share (%)[b]	19.5	2.8	14.0	24.7
Cholesterol Health Index	1182.8	467.8	516.6	2001.7
Beef Food Safety Recalls	2.14	2.05	0	11
Pork Food Safety Recalls	1.76	1.85	0	7
Poultry Food Safety Recalls	1.59	1.50	0	8
Females in Labor Force (%)	56.8	2.32	51.8	60.1

[a] Inflation-adjusted dollars (deflated by CPI, 1998=100).
[b] Share of total meat expenditures.

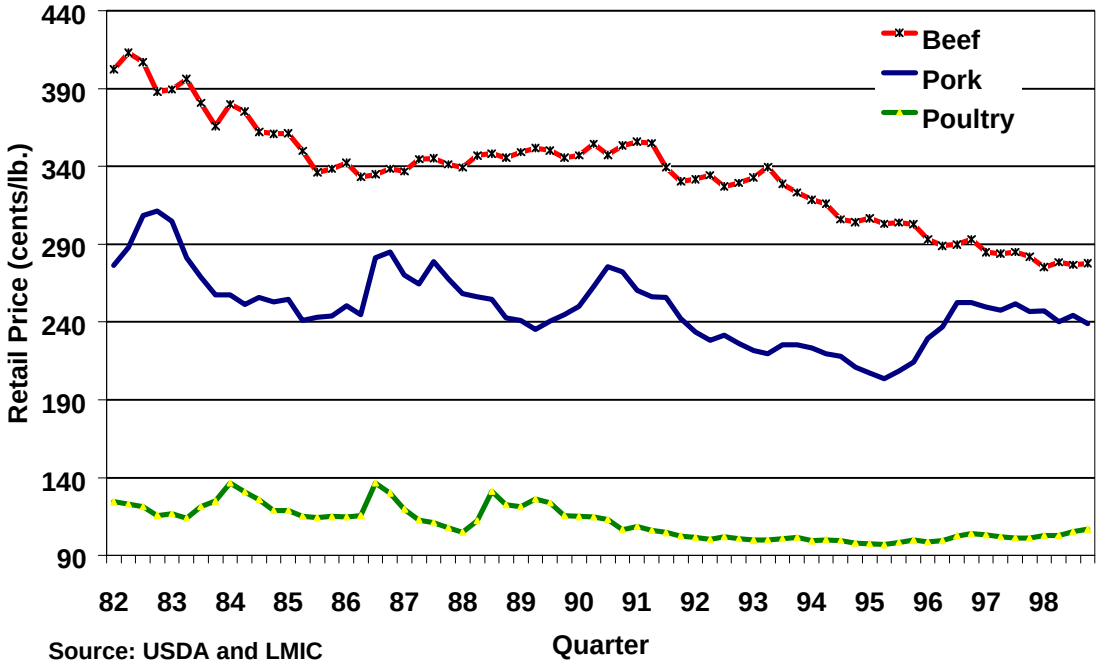
Figure 9. Quarterly Per Capita Beef, Pork, and Poultry Consumption, 1982-98



Source: USDA and LMIC

Retail beef price had the highest average among competing meats at 335.36 cents/lb. expressed in 1998 dollars (Table 2). Pork price had the next highest average at 249.15 cents/lb. and poultry price averaged 110.77 cents/lb. Trends in the prices are illustrated in Figure 10. Inflation-adjusted beef price declined from a high of 413.09 cents/lb. in second quarter 1982 to less than 280 cents/lb. throughout 1998. Pork price peaked at 311.56 cents/lb. in fourth quarter 1982, hit its low near 190 cents in 1995 and rebounded to average above 240 cents every quarter but one since 1996. Retail poultry price ranged primarily from 115 to 135 cents/lb. during 1982-90 and then fell to the 95 to 105 cent range during the 1990s. Retail beef price declined relative to both pork and poultry prices during the 1982-98 period. In the first quarter of 1982 beef price was 1.5 times greater than pork price and 3.2 times poultry price. By 1998 beef price was only 1.14 times pork price and 2.66 times poultry price. This finding is important because relative prices influence which meat products consumers will purchase.

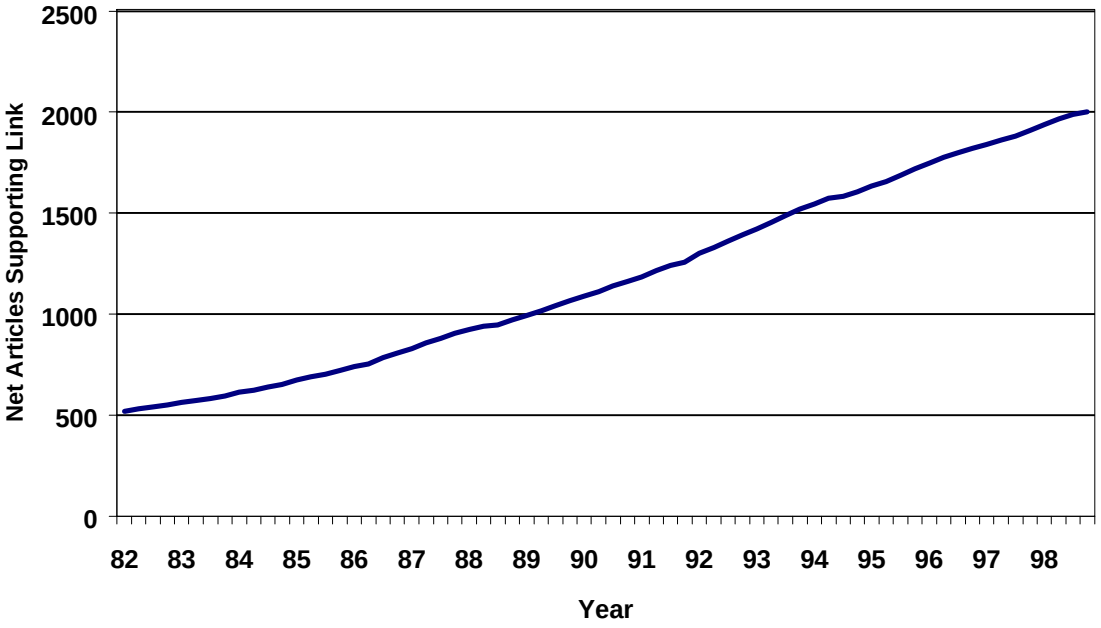
Figure 10. Inflation-Adjusted (1998 Dollars) Quarterly Beef, Pork, and Poultry Prices,1982-98



Source: USDA and LMIC

The cholesterol health index, measured as the cumulative number of medical journal articles supporting minus those refuting links between cholesterol and heart disease was trending upward throughout 1982-1998 (Figure 11). The index started in 1966 with a value of zero and by 1982 a total of 545 articles had been published supporting the link between heart disease and cholesterol whereas, only 30 articles were published that refuted the link. Since 1982 the number of articles published supporting the link, less those refuting it, has averaged 22 articles per quarter, although it has been increasing at an increasing rate.

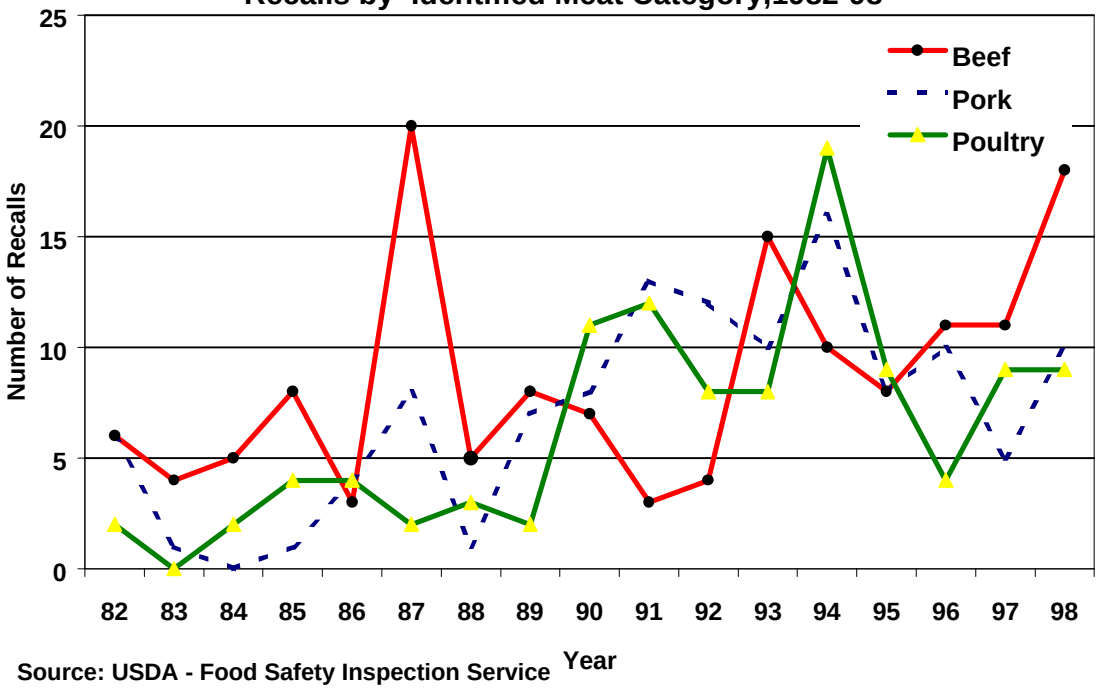
Figure 11. Cumulative Net Number of Articles Supporting Cholesterol and Heart Disease Linkage, 1982-98.



Source: Brown and Schrader and own collection

Food safety inspection service meat recalls averaged 2.1 per quarter for beef, 1.8 for pork, and 1.6 for poultry from 1982 to 1998 (Table 2). The number of recalls varies from year to year (Figure 12). Beef experienced its highest number of recalls in 1987 at 20. However, during the last three-quarters of 1998 beef had from 4 to 8 recalls each quarter and a total of 18 for the year. In contrast, pork and poultry each had 4 or fewer recalls during each quarter of 1998. Product recalls during 1998 for pork and poultry totaled 10 and 9, respectively.

Figure 12. Annual Number of Food Safety Inspection Service Recalls by Identified Meat Category,1982-98



Source: USDA - Food Safety Inspection Service

Table 3 summarizes FSIS recalls by meat product and type of recall over the 1982-November 1999 period. Beef has had more recalls due to bacteria contamination than any of the other meat species with 81 recalls compared to 59 for pork and 32 for chicken and turkey combined. Perhaps even more alarming is that the first *E. coli* O157:H7 FSIS recall recorded since 1982 (beef's most common bacterial contamination problem) did not occur until 1988. Thus, detection of *E. coli's* presence has been much more common in recent years than during the early and mid-1980s. Beef and pork also tend to have more frequent extraneous material contamination of products compared to competing meats. Overall, beef had the highest number of total recalls over this time frame with 168 followed by 157 for pork, 71 for chicken, and 44 for turkey. In the demand model estimation in this study the "Other Meat" and the "Processed Product" recall data are not included in the model since they were not identified by specific meat species.

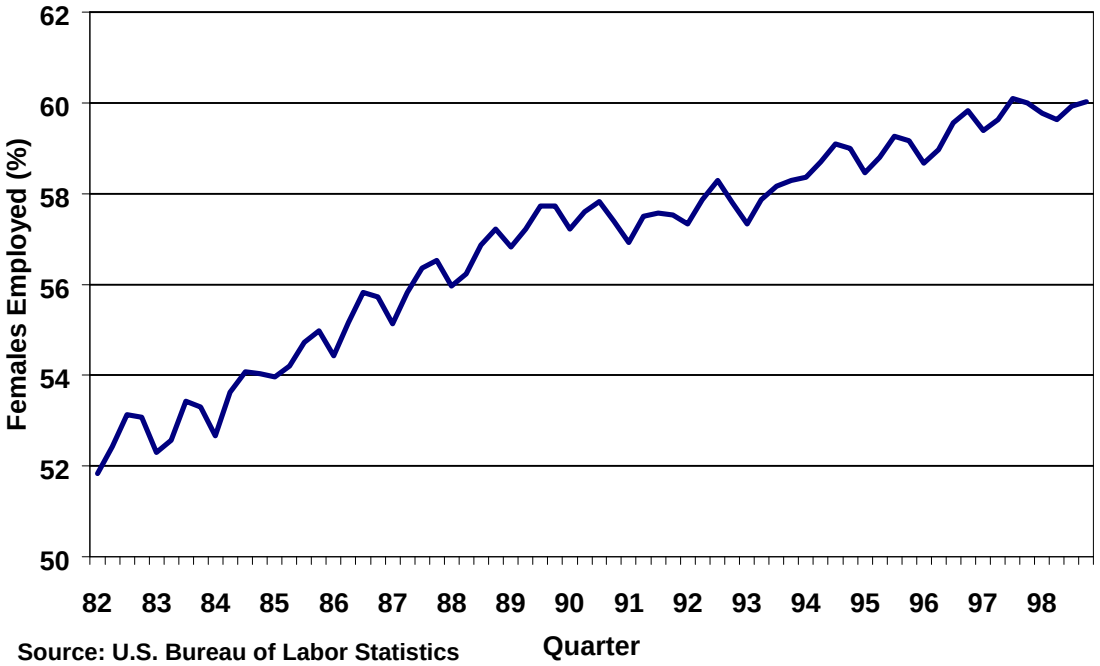
Table 3. Meat Product Food Safety Inspection Service Recalls, 1982 – November 1999.

Recall Type:	Beef	Pork	Chicken	Turkey	Other Meat[a]	Processed Products[b]
Salmonel1a	16	10	2	0	1	2
Listeria	24	39	14	4	34	4
E. Coli O157:H7	34	3	0	0	0	0
Staphylococcus	1	3	0	0	0	0
Trichinae	0	3	0	0	0	0
Other Bacteria	6	1	4	8	1	3
Hepatitus A	0	1	1	0	0	0
Extraneous Matter[c]	40	49	31	23	18	12
Species Problem	23	4	1	0	11	0
Other Reasons[d]	24	44	18	9	17	10
Total Recalls	168	157	71	44	82	31

[a] Includes products such as hot dogs, luncheon meats, spreads, etc. that are not identified by species.
[b] Includes processed products such as soups, ravioli's, stews, etc. not identified specifically as containing meat or by meat species.
[c] Includes extraneous materials, drugs, chemicals, rodent and insect contamination, etc.
[d] Includes primarily product labeling, package damage, under-processing, odors, etc.

Female labor force participation was increasing throughout the 1982-98 period. Over the entire time frame an average of 56.8% of females were employed outside the home. Female labor participation in the early 1980s was just over 50%, but climbed to 60% by late 1998 (Figure 13). The ongoing increase in female labor force participation suggests demand for food product convenience was increasing as work time detracted from time available for food preparation.

Figure 13. Quarterly Percentage of Females Employed Outside the Home, 1982-98.



Source: U.S. Bureau of Labor Statistics

Estimation Issues

Several estimation issues arose in the process of estimating the demand system. Initially, the meat demand system was comprised of beef, pork, chicken, turkey, and other consumption goods equations where total per capita personal consumption expenditure is used in place of income. In this specification chicken and turkey were estimated as separate demand equations. However, contrary to economic theory, the own price elasticities were positive for a large number of observations. To correct for this (for justification see Piggott, 1997; Eales, Hyde, and Schrader,1998), chicken and turkey were aggregated to form a single poultry variable. The poultry price was constructed by summing together, in each quarter, total expenditures on chicken and turkey divided by per capita poultry consumption. Thus, the reformulated demand system consisted of beef, pork, poultry, and other goods equations.

To account for possible lagged effects on meat demand, both current and lagged values of the health index and the FSIS recalls were included in the model. The current and lagged

health index variables were highly collinear, which is due to the cumulative nature of the index. Furthermore, a likelihood ratio test revealed that parameter estimates for lagged values of the health and FSIS recall variables were not significantly different from zero. As a result, the final model included price and expenditure variables, the percentage of females in the labor force, the current period health, and food safety indices.

Many demand models estimated in the literature contain trend variables along with other demand shifters. Trend variables are intended to capture effects over time that are trending up or down not accounted for in other measured variables. Although trend variables may help explain past consumption patterns, they are not very informative in demand modeling if one wants to identify the factors causing the trend. Thus, trend variables were not included in the demand models estimated here. Instead variables such as demographic factors and health information over time, that exhibit trends, are included directly in the model as demand shifters.

Demand Estimation Results

Detailed statistical estimates of the demand model are reported in the Appendix. The equations explained a large share of the variability (from 78% to 89%) in beef, pork, and poultry consumption over the time period. Elasticity estimates of the results are reported in Table 4. Elasticities measure the percentage change in the quantity of the dependent variable (e.g., beef quantity) given a one percent change in the independent variable (i.e., beef price, pork price, poultry price, etc.). Overall the estimated price, expenditure, and non-price effects are consistent with prior expectations and results of previous studies. Details of the price, expenditure, and non-price variables are discussed below.

Table 4. Estimated Compensated Elasticities for Meat Demand Model, Quarterly Data 1982-1998[a]

	Quantity of:			
With Respect to:	Beef	Pork	Poultry	Other Goods
Beef Price	-0.608	0.078	0.045	0.002
Pork Price	0.041	-0.503	-0.0006	0.0008
Poultry Price	0.016	-0.0004	-0.053	0.00001
Other Goods Price	0.550	0.424	0.007	-0.003
Expenditure	0.900	0.731	-0.403	1.003
Beef Recalls	-0.0065	-0.0070	-0.00038	0.000036
Pork Recalls	0.000009	0.002602	0.001086	-6E-06
Poultry Recalls	0.00048	0.0022	-0.0028	-2E-06
Health Information	-0.0535	0.118	0.187	-0.0003
Female Labor Force	-1.512	-1.450	0.457	0.007

[a] Elasticites are calculated at the mean values of the explanatory variables.

Beef and Competing Meat Price Effects
The estimated own-price elasticities are -0.61, -0.50, and -0.05 for beef, pork, and poultry, respectively. This indicates a 1% increase in beef price causes a 0.61% decline in per capita beef consumption. The cross-price elasticities are positive for beef and pork, indicating they are substitutes. In particular, a 1% increase in pork price causes a 0.04% increase in beef consumption and a 1% increase in poultry price increases beef consumption by 0.02%. These results are similar to Kinnucan *et al*. (1997), Piggot (1997), and Capps and Schmitz (1991).

Expenditure
Total per capita expenditure was jointly a significant determinant of beef, pork, and poultry demand. Elasticity estimates were 0.90 for beef, 0.73 for pork, and -0.40 for poultry. This implies that beef is the most sensitive to changes in total expenditures, followed by pork, and then poultry. In addition, this result indicates poultry is an inferior good with consumers consuming less poultry as personal expenditures increase, with all else constant. This finding means beef is the biggest gainer of the three competing meats when consumers increase per capita expenditures and the biggest loser when they reduce expenditures.

Health
The estimated impacts of health information on meat demand are similar to those reported by Kinnucan *et al.* (1997) and McGuirk *et al*. (1995). The elasticities at the mean over the 1982 to 1998 period are -0.05, 0.12, and 0.19 for beef, pork, and poultry, respectively. This indicates as more articles are published supporting the linkage between cholesterol and heart disease, beef demand declines modestly, whereas, pork and poultry demand increase. Important to recall is that the health index trended upwards over time (Figure 11) which means its estimated elasticity could also be reflecting other consumer demand trends that occurred from 1982 to 1998.

Over the study period the magnitude of the health elasticities for beef , pork, and poultry increased dramatically. The health elasticity for beef in 1982 was -0.02 while in 1998 it was -0.15. The health elasticity for pork was 0.04 in 1982 compared to 0.23 for 1998. For poultry the health elasticity was 0.08 in 1982 versus 0.32 in1998. Thus, over this time period the importance of the health elasticity increased for both beef (negatively) as well as pork and poultry (positively).

Female Labor Force
The percentage of females in the labor force had a significant impact on the demand system. Note that the percentage of females in the labor force was trending up over time, indicating that (like the health index variable) it may also be reflecting the importance of other factors that exhibited similar trends during this period. Results indicate that an increase in the percentage of females in the labor force had a significant, negative impact on beef and pork consumption, but a positive, significant affect on poultry consumption. For each 1% increase in female labor force participation, beef consumption declined by

1.51% whereas poultry consumption increased by 0.46%. The results for beef and poultry are similar to those reported by McGuirk *et al*. (1995).

When examined over the entire study period, the magnitude of the female labor force elasticities for beef and pork increased substantially, whereas they increased moderately for poultry. Elasticities for 1982 were -0.89 (beef), -0.97 (pork), 0.40 (poultry) and for 1998 were -2.59 (beef), -1.75 (pork), and 0.49 (poultry). Assuming female labor force participation is a measure of consumer demand for increased convenience, this suggests the poultry sector has benefited over time by offering more convenient products to consumers. At the same time, beef demand has suffered as time allocated for food preparation declined and the beef industry offered few product developments to reduce product preparation time.

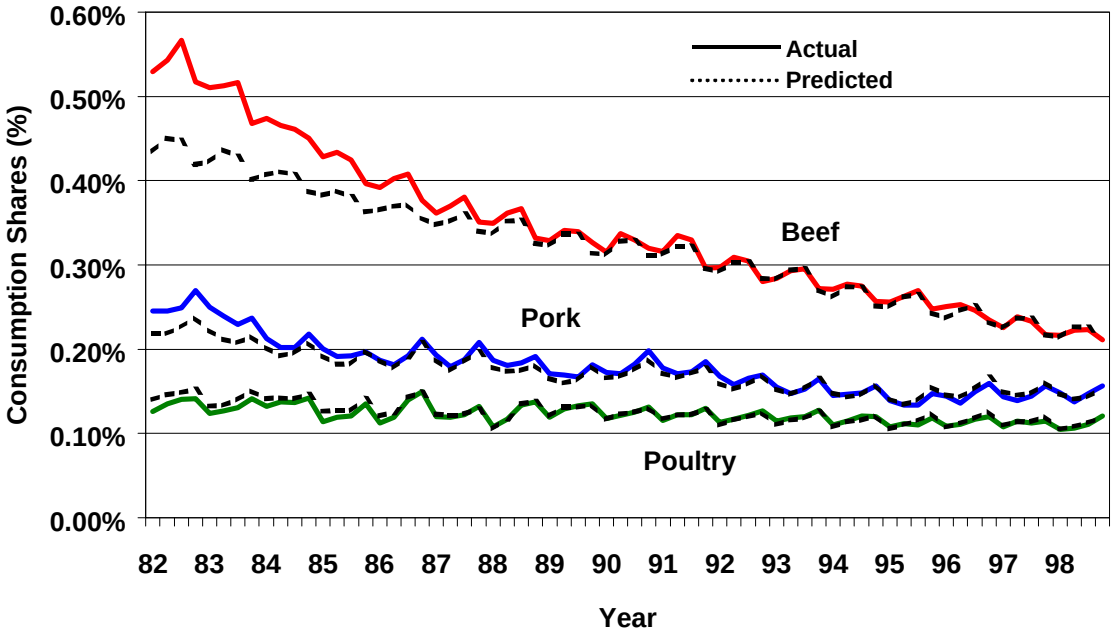
Food Safety

FSIS recalls have a negative impact on retail beef demand. Beef recalls averaged 2.1 per quarter from 1982 to 1998, but the number of recalls varied greatly from quarter to quarter and year to year. For example, beef recalls ranged from 4 to 8 per quarter during 1998. The meat demand model indicates that during certain years beef recall events resulted in more than a 0.5% decline in per capita beef consumption from the previous year. FSIS meat recalls also have cross effects. For example, increases in beef recalls had a significant negative impact on pork and poultry demand and increases in pork recalls had a positive, but not significant, impact on beef and poultry consumption. Similarly, increases in poultry recalls had a positive, but not significant, impact on beef and pork consumption. Over the 1982-1998 period the number of FSIS recalls were small enough that the impact on beef demand was generally small. But the demand model results indicate a large increase in beef recalls would result in a significant downward beef demand shift. These results imply the beef industry cannot afford to be passive and simply react to food safety problems after they occur. Rather, the industry needs a proactive food safety program to minimize the negative impact on beef demand associated with FSIS recalls.

Model Performance

To illustrate the demand model's performance, the actual and demand-model-predicted budget shares for beef, pork, and poultry are presented in Figure 14 from 1982-1998. The budget share in a particular year for beef, for example, is consumer expenditures on beef divided by total personal consumption expenditures. From first quarter 1982 to fourth quarter 1998 the share of beef expenditures trended downward from 0.53 to 0.22%. Meanwhile, pork expenditures decreased from 0.25 to 0.16% and poultry decreased slightly from 0.13 to 0.12%. Not shown in Figure14 is the share of other consumption goods, which increased from 99.10 to 99.51% over the study period.

Figure 14. Actual and Demand-Model-Predicted Quarterly Beef, Pork, and Poultry Expenditure Shares, 1982-1998.



From 1982 until the mid- to late 1980s the predicted beef and pork shares underestimated actual shares of consumption, while predicted poultry shares overestimated actual shares. However, from the late 1980s through 1998, the predicted budget shares accurately reflect the actual budget shares for beef, pork, and poultry. This indicates that the variables specified in the demand model do not fully explain the drastic decline in meat consumption in the early to mid-1980s. More importantly, the variables specified in the demand model appear to adequately explain meat consumption from the mid-1980s through 1998. To measure the in-sample information value of the demand model's predictions in a scientific manner, Theil's Information Inaccuracy Statistic was calculated (Theil and Mnookin, 1966). Values of Theil's statistic close to zero indicate a low information *inaccuracy*, which is the preferred result. For the predicted and actual budget shares (beef, pork, poultry, and other goods), the calculated value of Theil's statistic was 0.0013, indicating that predictions from the demand model are very informative.

Including female labor and health information variables with price and expenditure variables in the demand model helped capture the long-run trends over the study period. Note that the price and expenditure variables are nearly all statistically significant in all four equations in the demand model (reported in the Appendix). The female labor force variables are highly significant in the beef and pork equations, while insignificant for the poultry equation. In other words, the female labor force participation variable helps explain the decline in per capita beef and pork consumption, but not the growth in poultry consumption. In contrast, the health information variable was significant in the poultry equation, while insignificant in the beef and pork equations. This suggests that response to health information may help explain the observed growth in per capita poultry consumption, but not necessarily the decline in per capita beef consumption.

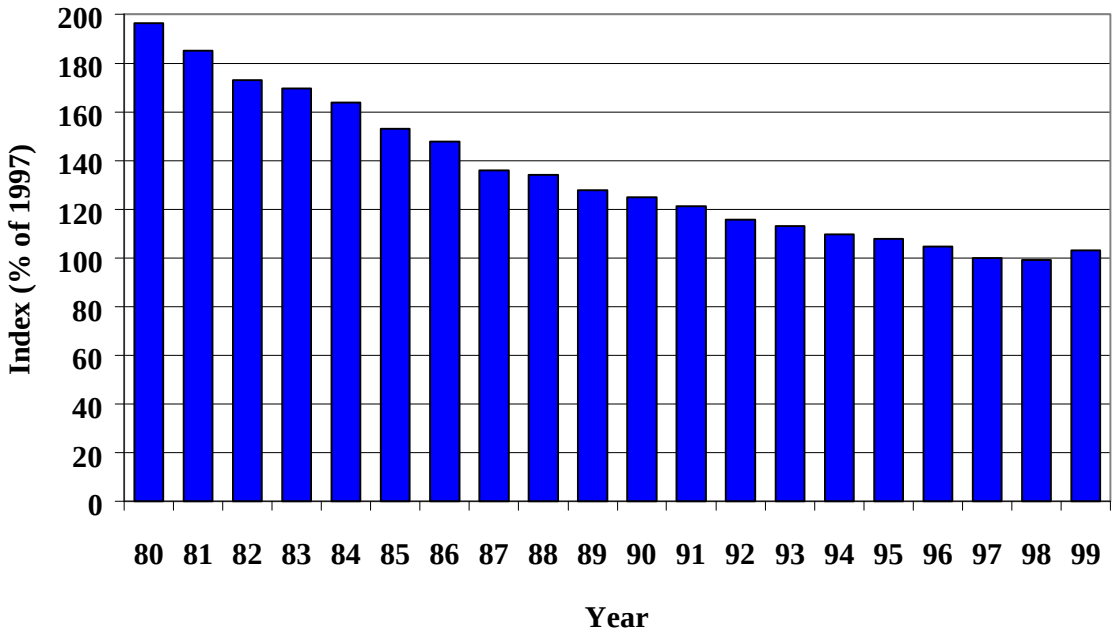
In addition to long-run trends, seasonal variation in actual budget shares for beef, pork, and poultry within each year are evident in the data series. The predicted shares sufficiently capture the seasonal variation in each series. The predicted budget shares for beef were highest in the second and third quarters, followed by the first and fourth quarters. The shares for pork and poultry were highest in the fourth quarter of each year. The parameter estimates, and the associated statistical tests, for the seasonality variables are reported in the Appendix. Overall, summary statistics from the model estimation (reported in the Appendix) indicate that the model explained 84%, 89%, 78%, and 89% of the variation in shares of beef, pork, poultry, and other goods respectively.

Allocation of Beef Demand Changes

To understand how the various factors in the demand model individually impacted demand historically, and to determine how much of the demand shift from year-to-year was not explained by variables included in the model, the demand shifts were disaggregated for each year. The allocation of demand shifts attributable to individual factors was conducted over the 1992-1998 historical (in-sample) period and projected using preliminary data for 1999 (out-of-sample). Details regarding the procedure followed are provided in the Appendix. Essentially, the demand allocation is the estimated vertical percentage shift in beef demand (calculated using the demand model estimates) from one year to the next, holding quantity at the previous year's level.

Prior to presenting the individual year-to-year demand shifts it is useful to consider the beef demand index developed by Purcell. This index measures the vertical shift in beef demand over time indexing relative to 1997 (i.e., 1997=100). The beef demand index is reported in Figure 15. Beef demand declined from an index value of just under 200 in 1980 to 100 in 1997 and 1998 meaning demand essentially declined by 50% over this time period. The index increased modestly from roughly 99 in 1998 to about 103 in 1999.

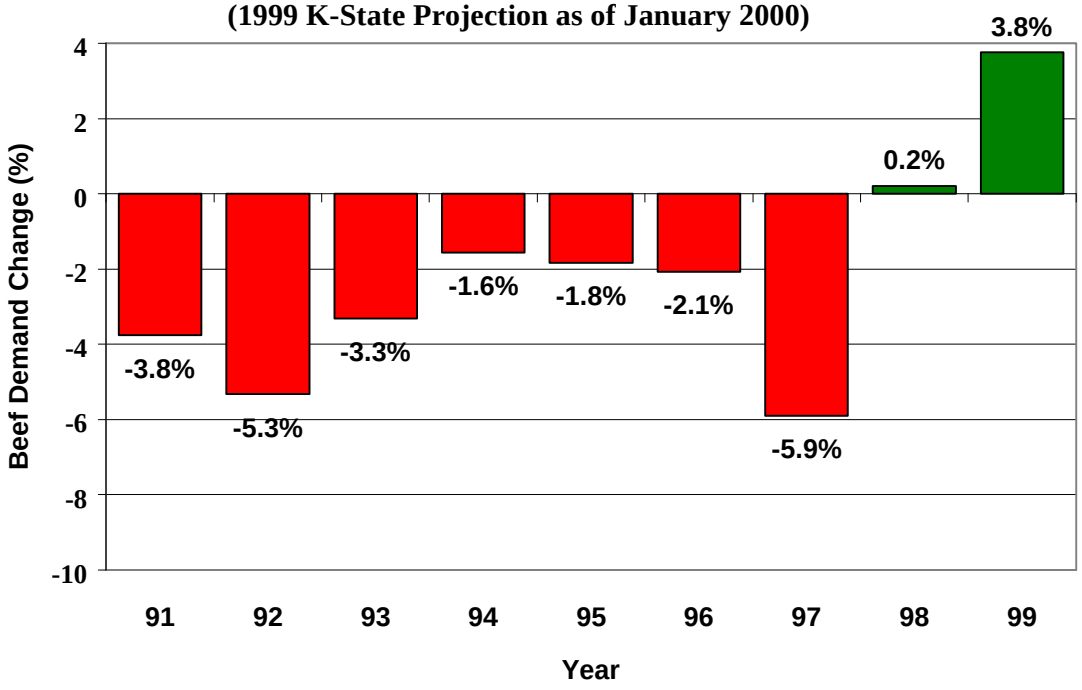
Figure 15. Choice Retail Beef Demand Index, 1980-1999 (1997=100)



Source: W. Purcell, Virginia Tech University

The ensuing analysis closely reviews the percentage changes in demand from year to year just since 1991. That is, this analysis essentially explores the year-to-year changes in the annual beef demand index that occurred from 1991 to 1999. During every year from 1991 to 1997 beef demand declined with the magnitude of the vertical demand shift ranging from 1.6% in 1994 to more than 5% in 1992 and 1997 (Figure 16). *For the first time since prior to 1980, beef demand stabilized in 1998 relative to 1997 and, based on preliminary data, beef demand appears to have increased (by about 3.8%) in 1999 relative to 1998.* Although noteworthy, the increase in beef demand in 1999 is modest and pales when compared to the cumulative magnitude of demand decline that occurred from 1982 to 1997.

Figure 16. Annual Percentage Change in Beef Demand, 1991-99 (1999 K-State Projection as of January 2000)



Figures 17 to 24 illustrate the estimated decomposition of meat demand from 1992 to 1999. The 1992 to 1998 decompositions are calculated within the demand model estimation period (i.e., in-sample) and the 1999 analysis is beyond the period of model estimation (i.e., out-of-sample).

Consider Figure 17 as an example. From 1991 to 1992 the beef demand curve shifted down vertically about 5% (see Figure 2 for a depiction of such a shift). This downward shift was allocated to the various demand determinants. Increases in total consumer expenditures contributed to a 3% upward shift in beef demand. Pork and poultry prices

both declined in 1992 relative to 1991 with pork contributing a 0.6% and poultry another 0.1% decline in beef demand. The health index increased contributing another 0.9% demand decline, and female labor participation increased contributing a 1.2% demand decline. Changes in prices of all other goods contributed to a 1.6% decline in beef demand. Beef recalls reduced beef demand by 0.4% and pork and poultry recalls had virtually no observed effect on beef demand in 1992 relative to 1991. Finally, all changes in demand determinants included in the demand model combined predicted a 3.7% smaller beef demand decline than was actually observed (i.e., the model predicted a 1.7% decline in demand whereas the actual decline was 5.3%). Thus, the unexplained value in Figure 17 is –3.6% (-5.3% minus -1.7%).

Over the study period, the impact on beef demand from changes in beef, pork, and poultry recalls were generally small. Although in 1993, when the number of beef recalls jumped from 4 to 15, this reduced beef demand 2.9% (Figure 18). This helps illustrate that product safety can have a meaningful impact on beef demand in periods when the number of recalls increase markedly. The impact of changes in percentage of females in the labor force and health information had consistently larger effects on beef demand than recalls (with the exception of 1993 when the recall exceeded the health index impact, but not the female labor force participation impact). From year-to-year increased female labor force participation reduced beef demand by approximately 0.1% to 3.0% every year. Additional health information over time likewise reduced beef demand by approximately 0.4% to 0.9% every year. Changes in quantities of pork and poultry are also important in explaining changes in beef price, but vary in sign and magnitude from year-to-year depending on the direction and magnitude of the change.

Total consumer expenditures had a positive impact on beef demand every year from 1991 to 1999. That is, with all else constant, as consumers increase consumption expenditures, the demand model indicates they also increase beef expenditures. Consumer expenditures as a percentage of disposable income increased over time (Figure 8), as did consumer income. Increases in both variables caused beef demand to increase. This suggests beef demand declines would have been substantially greater (by typically 3% or more annually) than those observed had consumers not been spending more of their income each year.

The unexplained components of each beef demand shift are also presented in Figures 17-24. During certain years the unexplained component of the shift in beef demand is relatively small (e.g., the unexplained error is less than 2% in absolute value in 1992-1994, and 1999), suggesting the factors included in the model explained most of the observed changes in beef demand. However, in other years the unexplained shift in demand is larger. For example, in 1997 (the year with the largest absolute value of unexplained demand shift at –7.7%) given the changes in demand determinants from 1996, a small increase in beef demand was actually expected (Figure 21). Instead beef demand declined more than in any other year from 1991 to 1999 (5.9%). The presence of unexplained shifts in demand during certain years indicates other factors not accounted for in the model affected beef demand. Nevertheless, it is informative to note that these

shifts were not due to prices of competing meats, changes in total consumer expenditures, health information, food recall events, or the percentage of females in the labor force.

Figure 24 shows the projected effects of beef demand determinants on beef demand using preliminary data for 1999. From 1998 to 1999 beef demand appears to have increased by 3.8%. Interestingly, most of the economic fundamentals suggested beef demand would have declined from 1998 to 1999. That is, pork price, poultry price, the health information index, and female labor force participation all predicted a downward shift in beef demand in 1999. However, total consumer expenditures increased in 1999 and that provided a catalyst for beef demand to increase. Less than 0.3% of the 1999 beef demand increase appears to have been caused by factors not included in the model.

Figure 17. Actual Beef Demand Change and Expected Changes in Beef Demand Attributeable to Factors in the Model, 1991 to 1992

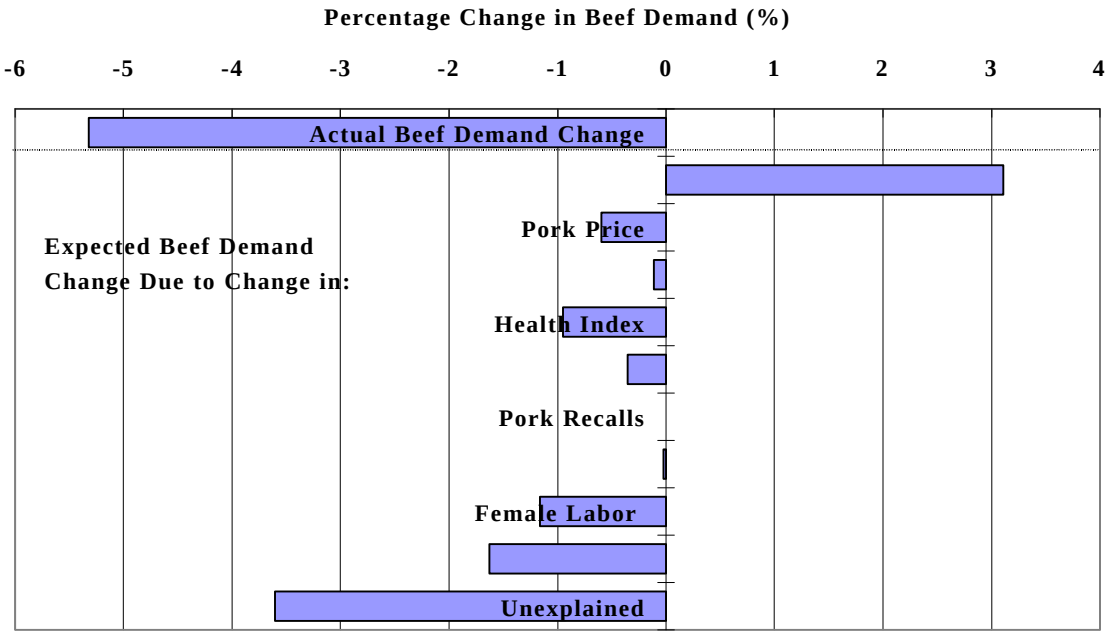


Figure 18. Actual Beef Demand Change and Expected Changes in Beef Demand Attributeable to Factors in the Model, 1992 to 1993

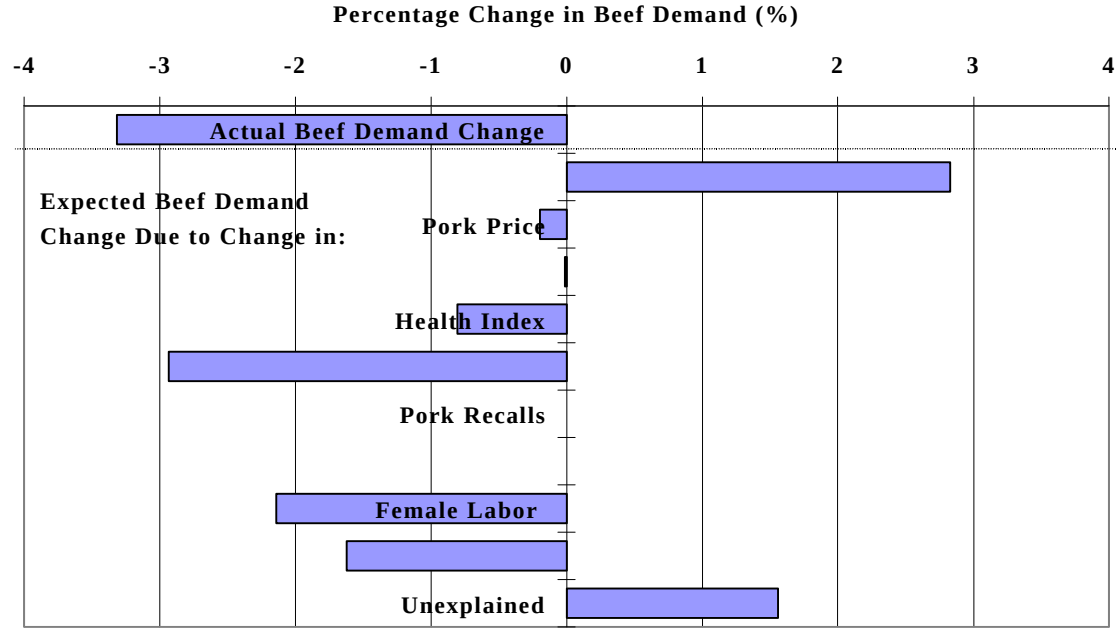


Figure 19. Actual Beef Demand Change and Expected Changes in Beef Demand Attributeable to Factors in the Model, 1993 to 1994

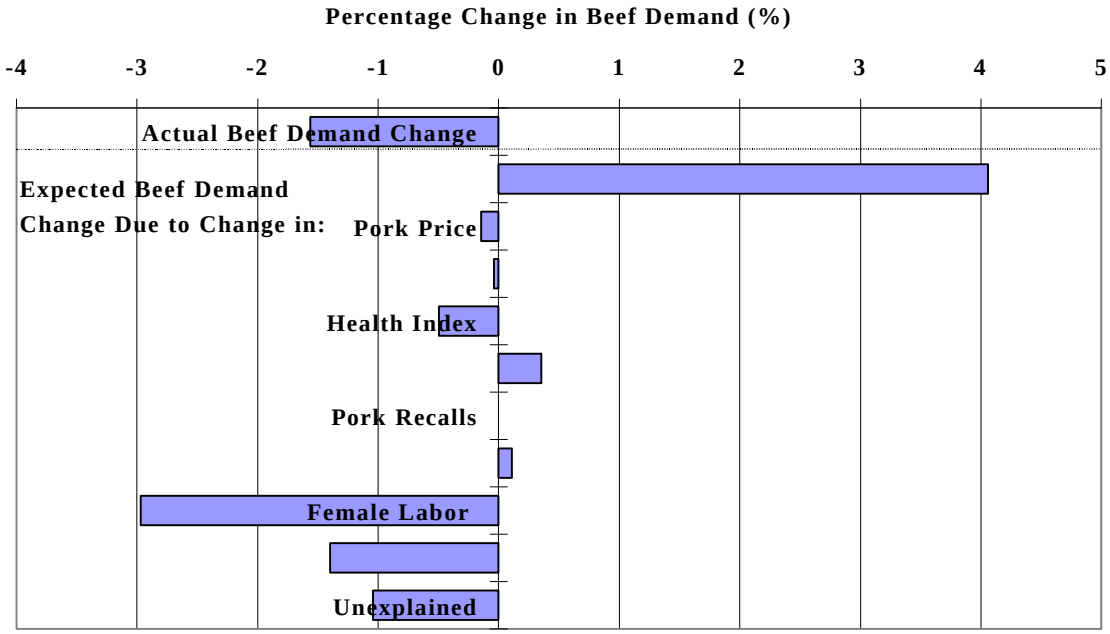


Figure 20. Actual Beef Demand Change and Expected Changes in Beef Demand Attributeable to Factors in the Model, 1994 to 1995

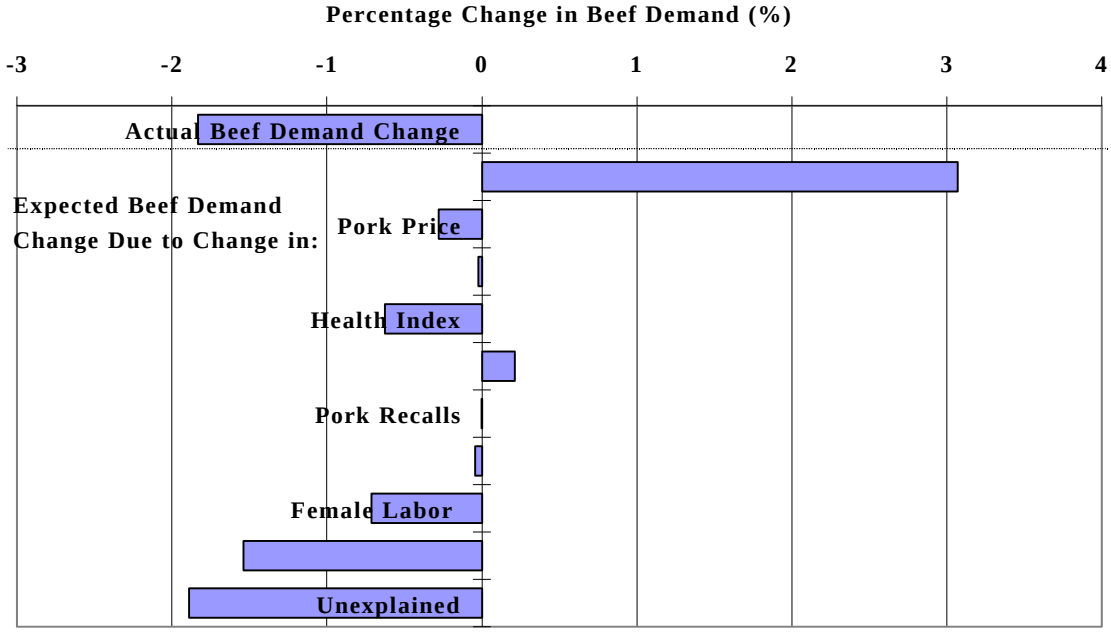


Figure 21. Actual Beef Demand Change and Expected Changes in Beef Demand Attributeable to Factors in the Model, 1995 to 1996

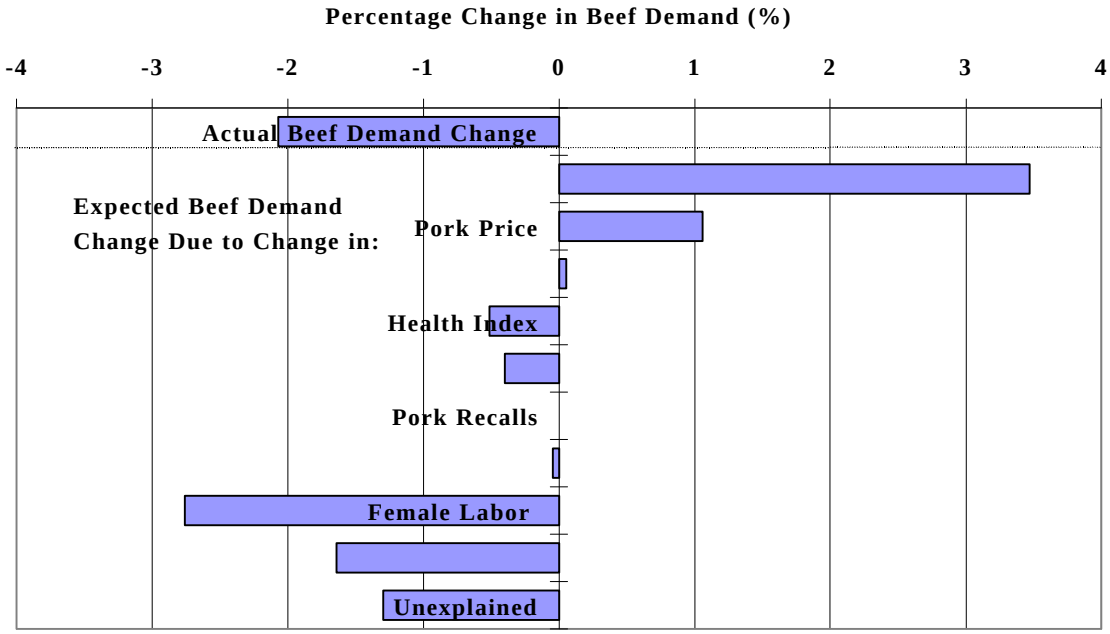


Figure 22. Actual Beef Demand Change and Expected Changes in Beef Demand Attributeable to Factors in the Model, 1996 to 1997

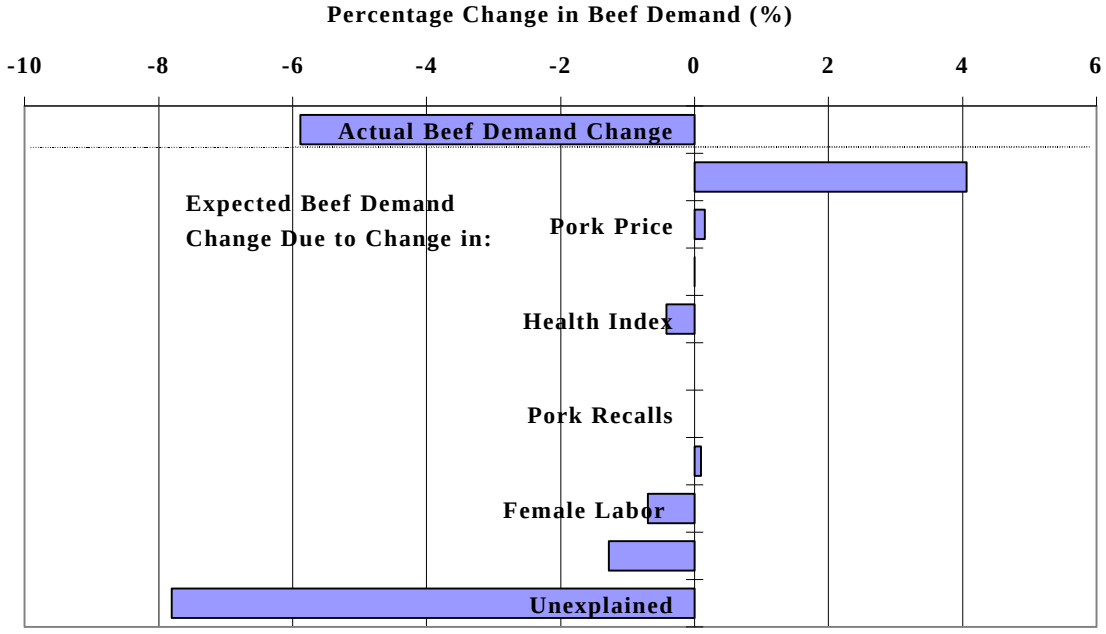


Figure 23. Actual Beef Demand Change and Expected Changes in Beef Demand Attributeable to Factors in the Model, 1997 to 1998

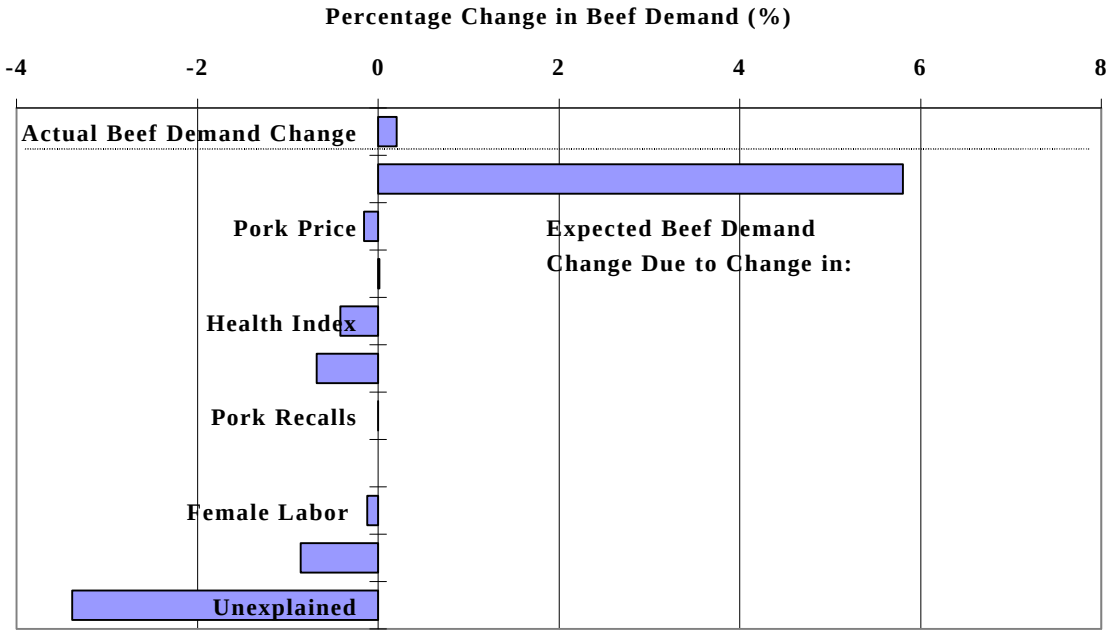
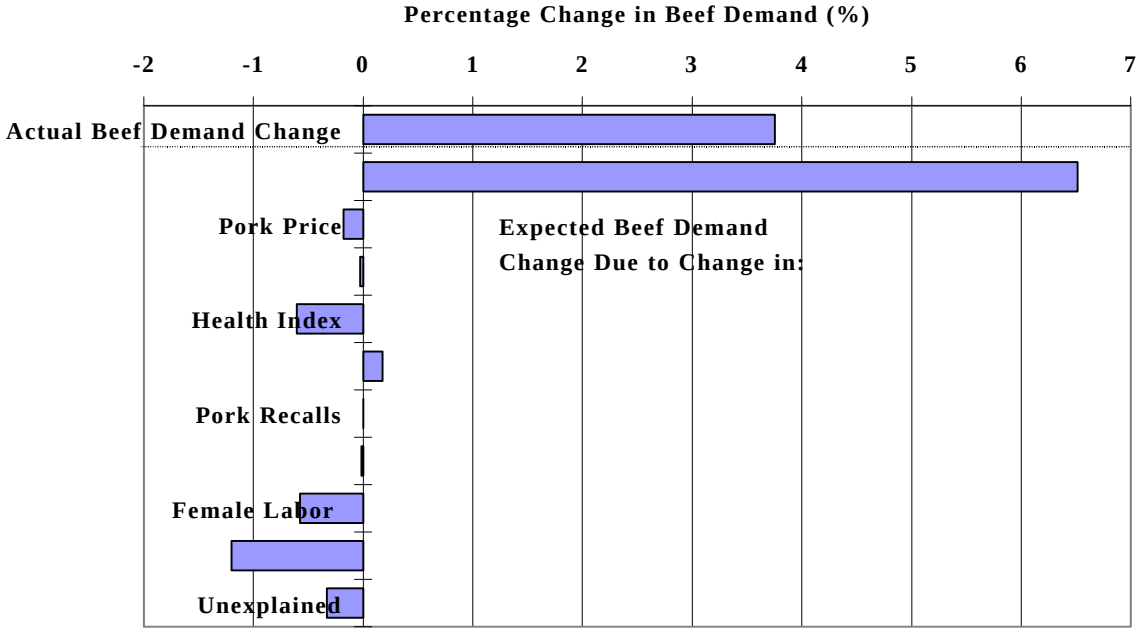


Figure 24. Actual Beef Demand Change and Expected Changes in Beef Demand Attributeable to Factors in the Model, 1998 to 1999



Conclusions

Beef demand declined precipitously from the late 1970s through the late 1990s. Generic beef promotion, consumer information programs, and the "war on fat" were launched by beef producers to combat the demand decline. But it has become increasingly clear that demand enhancement programs must be carefully targeted if they are to be effective at increasing long-run beef demand.

To aid in targeting demand enhancement programs, a comprehensive meat demand model capable of providing annual assessments regarding the factors that caused beef demand to shift, the direction of the shift caused by these factors, and the relative magnitude of the shifts attributable to each factor, was estimated. As expected, results indicated meat demand was sensitive to changes in prices of competing meats and consumer expenditures. But perhaps more importantly, a careful review of the impact several non-traditional meat demand determinants have on beef, pork and poultry demand suggests areas where the beef industry should consider committing resources if long-run improvements in beef demand are to occur.

Demands for beef, pork, and poultry, were inelastic over 1982-1998. Elasticity estimates suggest poultry demand (own price elasticity of -0.05) was more inelastic than beef (own price elasticity of -0.61) or pork (own price elasticity of -0.50) demand. The inelastic nature of beef demand means relatively small changes in quantity supplied lead to large retail meat price changes. This result is in part because beef represents a small proportion of total consumer expenditures. As consumer incomes rise, beef demand will remain inelastic, especially for high quality cuts that have few substitutes. As a result, consideration should be given to devoting resources to research focusing on quality (i.e., especially tenderness) measurement and improvement of high quality table cuts.

Information linking cholesterol and heart disease has had an impact on meat demand. As information about this apparent linkage has been disseminated via published medical literature, the result has been a downward shift in beef demand, whereas poultry demand actually increased. A 1% increase in the net number of articles positing the linkage between cholesterol and heart disease resulted in a 0.05% decline in the quantity of beef demanded by consumers. Conversely, a 1% increase in the net number of articles on this same topic resulted in a 0.19% increase in quantity demanded of poultry. These results confirm that beef demand has suffered, whereas poultry demand has benefited, from dissemination of information establishing the linkage between heart disease and cholesterol.

There are several programmatic implications of this linkage between articles that publicize heart disease risk and cholesterol. First, dietary guidelines that allow consumers on cholesterol restricted diets to keep beef in their diets need to be broadly disseminated. This type of program has already been developed with beef checkoff funding, but these results suggest it should be approached with new vigor. Second, research that examines the relationship between heart disease and cholesterol by cholesterol type and source could help refute conclusions from previous research on this

topic. Consideration should be given to funding more detailed research on the cholesterol-heart disease linkage and disseminating results within the medical community and among consumers.

Changing consumer demographics suggest consumers are placing more emphasis on how quickly meat items can be prepared for consumption. Declining time available for food preparation, as measured by female labor force participation, had a negative effect on beef demand. The percentage of females in the labor force rose from 52% in 1982 to 60% in 1998. As a greater proportion of females enters the labor force, less time is available for at home food preparation and consumption. The demand model results indicate that for each 1% increase in female labor force participation, beef demand declined by 1.51%. Moreover, results indicated the impact of changes in female labor force participation on beef demand was growing over time. Conversely, poultry demand actually increased as a larger percentage of females entered the labor force.

Consumers desire for greater product convenience is likely to grow over time. This means finding a way to reverse this negative impact on beef demand is imperative. The positive impact of increasing female labor force participation on poultry demand is attributable in part to the poultry sector's ability to develop new innovative products requiring less and less preparation time. The lesson for the beef industry is two-fold.

First, it confirms the need for the industry to commit resources to research and development with the intent of filling the product development pipeline with innovative, consumer friendly, easy to prepare beef items suitable for sale in a supermarket. Second, the industry needs to recognize that as consumers continue to place higher values on their time, demand for food consumed away from home will continue to increase. This means new product development cannot focus exclusively on beef items intended for home consumption. The beef industry must also pay attention to developing products suitable for purchase by consumers in a wide variety of dining establishments, ranging from low-priced fast food restaurants to high-priced white table cloth establishments.

Food safety concerns did not explain a large portion of the beef demand decline observed since the early 1980s. A direct measure of consumer concerns about food safety does not exist with time series data. But consumer concern about meat product safety is likely to be correlated with the number of meat product recalls that have occurred. Demand model estimation results indicated that, from 1982-1998, beef product recalls had a statistically significant negative impact on demand for beef. This suggests the beef industry needs to remain proactive, rather than reactive, on this issue as product safety seems likely to continue to become more important to consumers in the future.

To revitalize beef demand, the beef industry needs to be consumer focused. This means the industry must continually monitor consumer demand to detect and understand evolving demand changes. The research and analysis reported here needs to be updated periodically to provide beef industry leaders with information necessary to effectively monitor shifts in consumer beef demand. The industry must also design and implement programs that address and alter the beef industry's long-run demand decline.

Epilogue: What Happened In 1999?

Beef and cattle prices both increased significantly during 1999 compared to the previous year, despite the fact that beef and competing meat supplies were larger than in 1998. USDA's retail Choice beef price averaged $2.88 per pound compared to $2.77 in 1998, a nominal increase of 4%. Similarly, western Kansas slaughter steer prices rose from a 1998 annual average of $61.84/cwt to $65.86/cwt in 1999, an increase of 7%. The price increases were surprising because per capita beef, pork and chicken supplies during 1999 increased by approximately 1%, 2%, and 7%, respectively, compared to the previous year. Clearly, beef demand was stronger (i.e., the beef demand curve shifted out and to the right) in 1999 than in 1998, but why was beef demand stronger?

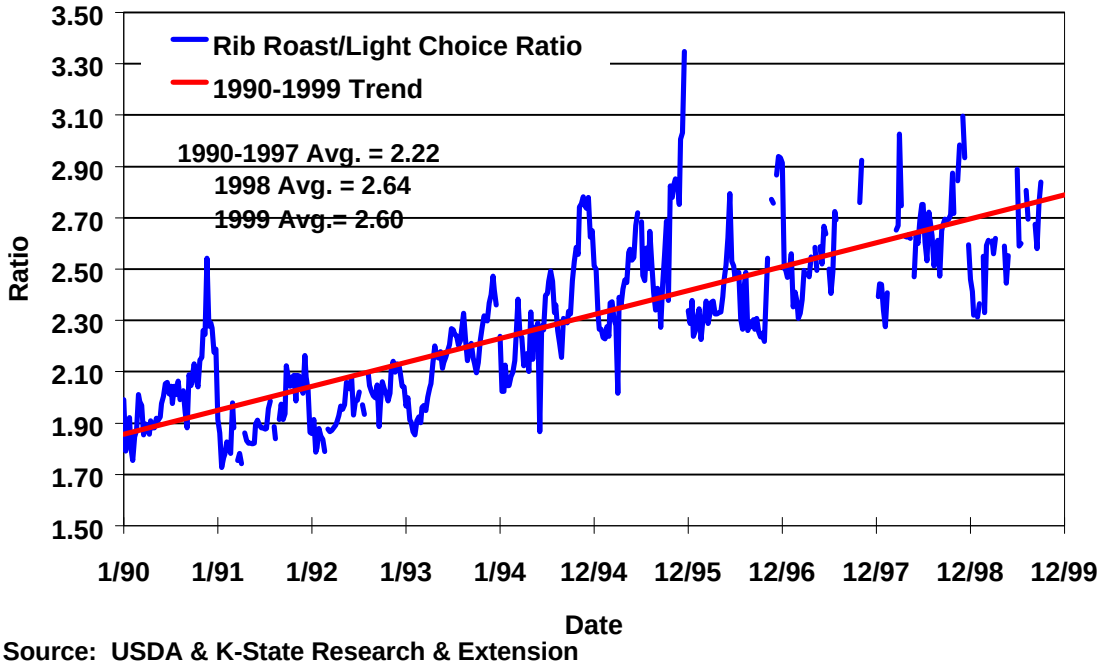
A variety of hypotheses have been posed by market analysts and in the popular press to explain the 1999 beef demand increase. These hypotheses can be summarized as falling into one of the following four categories. First, continued growth in the U.S. economy led to an increase in consumer disposable income and thereby provided a boost to beef demand. Second, strong demand for high quality beef cuts, partially driven by late year *millenium event* purchases, led to an increase in beef demand. Third, new product development and marketing (e.g., the introduction of several pre-cooked roast products) boosted demand for several lower-valued meat cuts resulting in an overall beef demand increase. Finally, some observers speculated that increasing emphasis on high protein diets, best noted by an increase in the number of news stories and book sales focusing on high protein (especially beef) diets, led to a beef demand shift. The first hypothesis can be examined by referring to the meat demand model detailed in this report. The second and third hypotheses can be examined by reviewing recent trends in prices of individual wholesale meat cuts. Unfortunately, empirical data to test the last hypothesis are not available.

The meat demand model detailed in this report indicates a number of factors affected beef demand, both negatively and positively, during 1999. Overall, beef demand in 1999 increased by approximately 3.8% compared to 1998 (Figure 24). The decomposition analysis indicates declines in pork, poultry and other good prices, and an increase in the number of females entering the labor force all had a small negative impact on beef demand during 1999. But the cumulative negative impact of these factors on beef demand was more than offset by reductions in beef product recalls and, especially, a 6% increase in consumer expenditures. The consumer expenditure increase was driven both by an increase of nearly 4% in consumer disposable personal income and by consumer willingness to consume an increasing portion of income. Thus the meat demand model results confirm that strong economic growth and consumer willingness to spending a growing portion of income provided a strong boost to beef demand in 1999.

But this does not directly address to what extent, if any, the millenium effect and/or new beef product development may have enhanced beef demand. To answer this question, the price pattern of various wholesale beef cuts was examined to determine if price strength

was focused on a few beef items or if it was spread across a wide variety of beef cuts. Prices were examined relative to the USDA's light Choice cutout value to identify whether a particular cut's price was strengthening or weakening, relative to overall changes in market prices. The presence of strong seasonality in the prices of several beef items made it imperative that changes in the relationship between a particular cut's price and the light Choice cutout value be examined over more than one year. As a result, the price ratios were examined both during the decade of the 1990's and, in detail, over the 1998-1999 period.

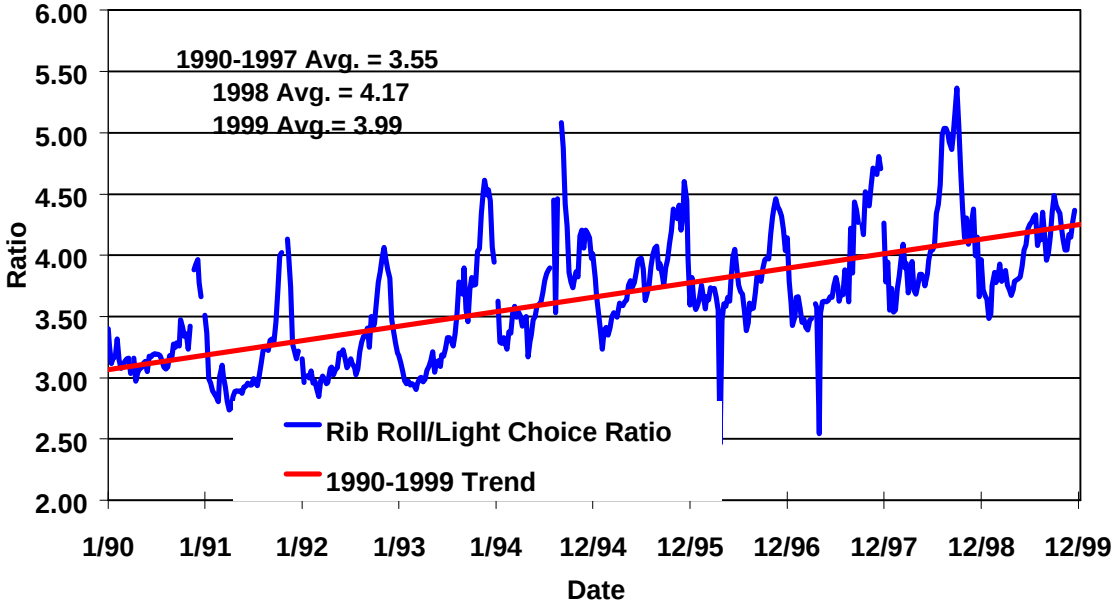
Figure 25. Weekly Ratio of Rib Roast #109 Price to Light Choice Boxed Beef Cutout Value, 1990-1999.



Source: USDA & K-State Research & Extension

Rib roast (#109) and rib roll (#112A) prices gained in importance relative to the Choice cutout value throughout the 1990s (Figures 25 and 26). Early in the decade, rib roast prices were approximately double the light Choice cutout value per cwt., but by the end of the decade they averaged 2.6 times the cutout value. However, little change occurred in rib roast prices relative to the cutout value in 1999 vs. 1998, suggesting that no major shift in rib roast demand occurred in 1999 relative to 1998. Similarly, rib roll prices averaged 3.25 times the cutout value in 1990, but were more than 4 times the cutout value in 1998 and 3.99 times the cutout in 1999. Once again, the rib roll price ratio does not suggest a significant shift in rib roll demand occurred in 1999 compared to 1998.

Figure 26. Weekly Ratio of Rib Roll #112A Price to Light Choice Boxed Beef Cutout Value, 1990-1999.

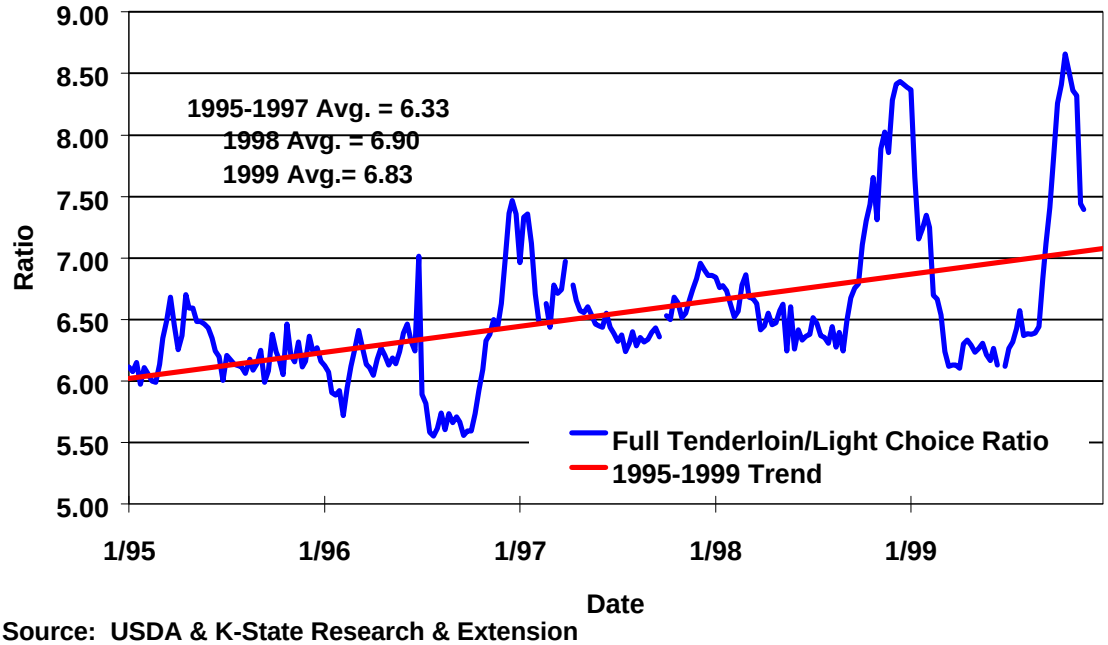


Source: USDA & K-State Research & Extension

Full tenderloin (#189) prices have clearly increased, relative to the Cutout value, in recent years (Figure 27). Although comparisons to the early part of the 1990s are tenuous since the quality and weight specifications have changed over time, it is clear full tenderloin prices have increased, even since the mid-1990s. For example, full tenderloins were priced at an average of 6.4 times the light Choice cutout value from 1995 through 1997, but in 1998 and 1999 full tenderloins averaged 6.9 and 6.83, respectively, times the light Choice cutout value. Although extraordinary strength in tenderloin prices did boost beef prices in late summer and fall 1999 (perhaps because of additional year-end, millenium effect demand), it appears what took place was primarily a continuation of the long-term trend of increasing consumer demand for tenderloins.

In contrast, demand for several beef cuts weakened appreciably during the 1990s as their prices declined relative to USDA's light Choice cutout value. For example, during 1990 top (#168) and bottom round (#170) prices averaged 1.38 and 1.21 times USDA's light Choice cutout value (Figures 28 and 29). But by 1998 the top round price ratio had slipped to 1.22 and the bottom round ratio declined to 1. Both ratios declined again in 1999, falling to 1.09 (top round) and 0.93 (bottom round). The fact that both top and

Figure 27. Weekly Ratio of Full Tenderloin #189 Price to Light Choice Boxed Beef Cutout Value, 1995-1999.

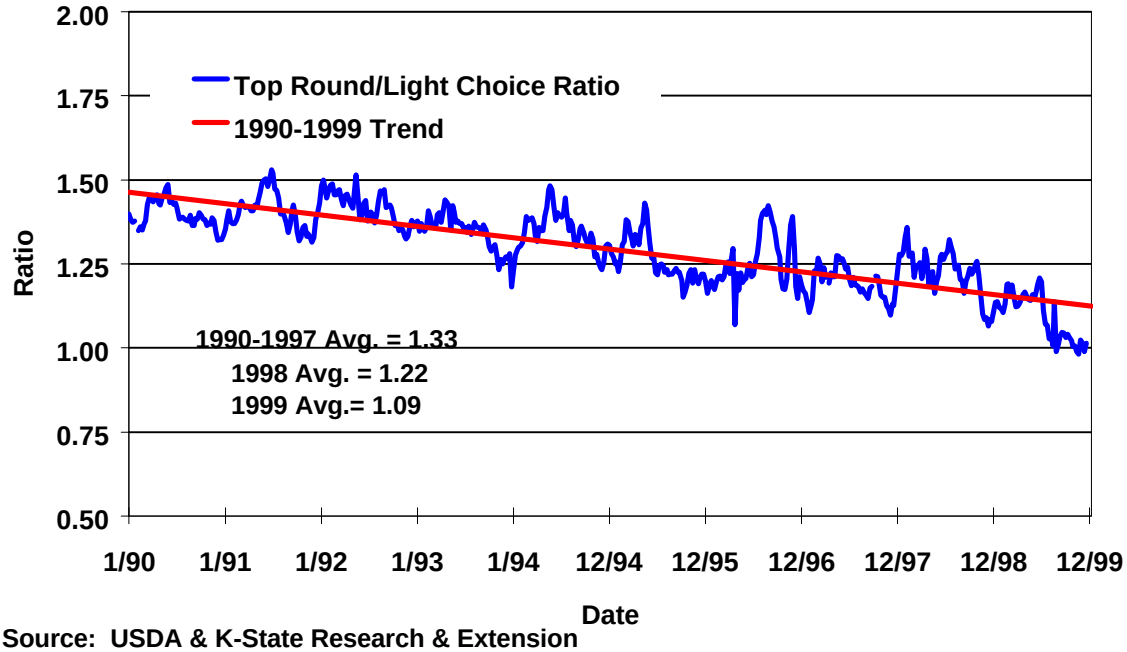


Source: USDA & K-State Research & Extension

bottom round prices were slipping during 1999, relative to the cutout value, is interesting since some observers have speculated that some of 1999s demand strength might be attributable to development of new products such as pre-cooked pot roasts. Since the source of these products is generally chucks and rounds, it appears these new products have not yet had a significant impact on round prices. Correspondingly, it also means the 1999 beef demand rebound is not explained by the introduction and marketing of new beef products. This is not surprising since the volume of these products is still quite small. Whether new product development has an appreciable positive effect on chuck and round demand will be tested over the next several years as product offerings and volume increase.

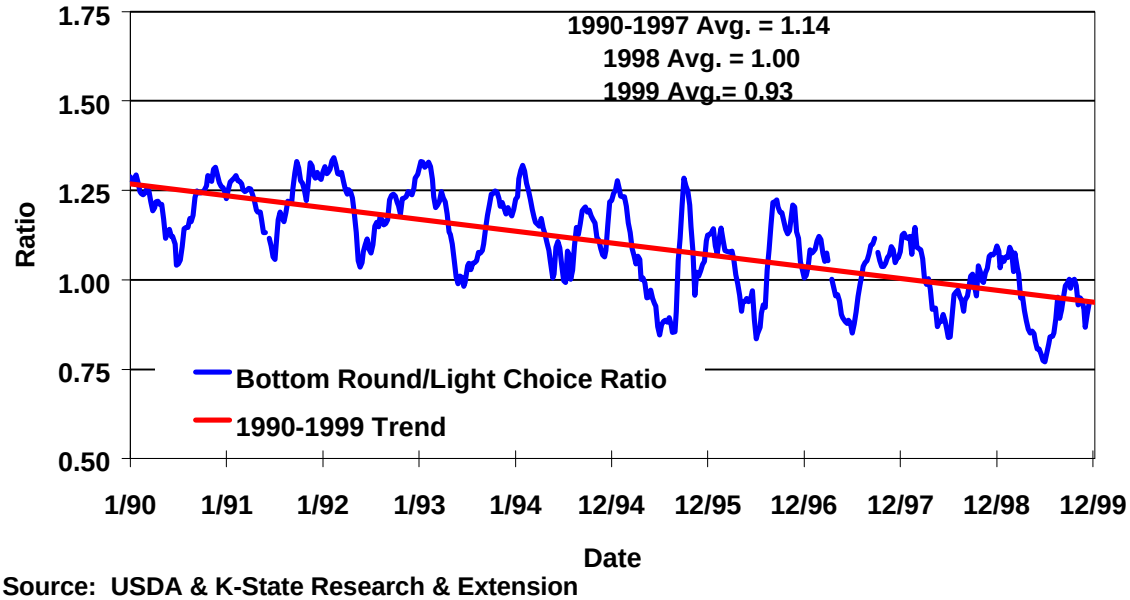
Ground beef product values declined relative to the cutout value during the 1990s. One way to see this is to examine the prices of two particular ground beef products, 90% and 50% lean ground beef. In 1990, prices for 90% and 50% lean ground beef averaged 1.08 and 0.48 times, respectively, the light boxed beef Choice cutout value (Figures 30 and 31). But by 1998 these price ratios had declined to 0.9 and 0.31, respectively. Prices for 90% lean ground beef, relative to the Cutout value, appear to have stabilized since early 1996, although the 90% lean price ratio declined slightly in 1999, falling to 0.86. In contrast, the 1999 50% lean price ratio increased slightly to 0.33. Prices for 50% lean ground beef exhibited the most strength late in 1999 as the price ratio moved up into the 0.40s during the last half of 1999. It is not clear what motivated the modest rebound in 50% lean values in late 1999.

Figure 28. Weekly Ratio of Top Round #168 Price to Light Choice Boxed Beef Cutout Value, 1990-1999.



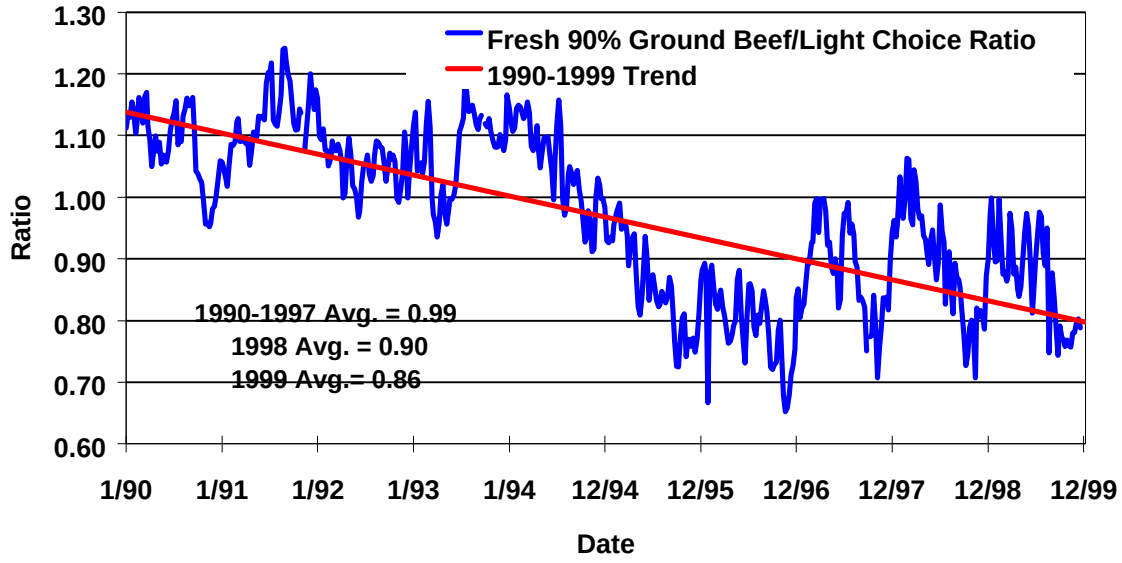
Source: USDA & K-State Research & Extension

Figure 29. Weekly Ratio of Bottom Round #170 Price to Light Choice Boxed Beef Cutout Value, 1990-1999.



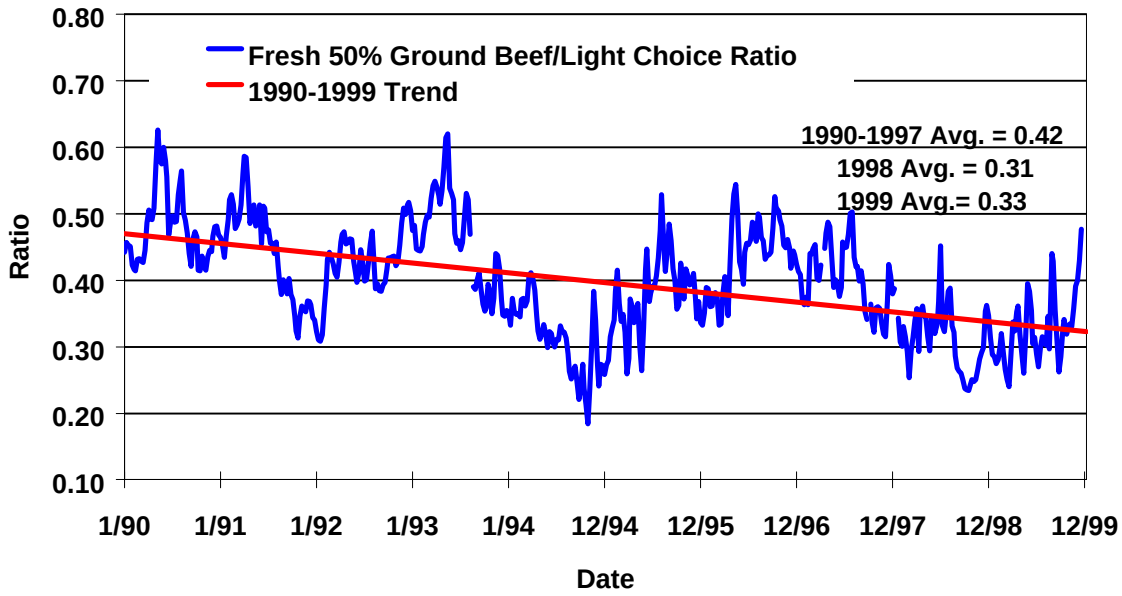
Source: USDA & K-State Research & Extension

Figure 30. Weekly Ratio of Fresh 90% Lean Ground Beef Price to Light Choice Boxed Beef Cutout Value, 1990-1999.



Source: USDA & K-State Research & Extension

Figure 31. Weekly Ratio Of Fresh 50% Lean Ground Beef Price to Light Choice Boxed Beef Cutout Value, 1990-1999.



Source: USDA & K-State Research & Extension

What do we know about what happened to beef demand in 1999?

1. Strong growth in consumer disposable income, combined with consumer willingness to decrease savings rates and spend larger proportions of total income than in 1998 had a large, positive, impact on beef demand during 1999. Model results indicate that growth in total consumer spending was largely responsible for the upward shift in retail beef demand and more than offset negative effects from a pork price reduction, and increases in the health index, beef recalls, female labor force participation, and reductions in prices of other goods.

2. Values of high quality cuts, such as full tenderloins, have been increasing relative to the light Choice cutout value for several years. This pattern continued in 1999, but it appears to have been a continuation of the long-term trend rather than a sharp jump from 1998 to 1999. Thus, increased consumer interest in high valued cuts, such as tenderloins, contributed to the 1999 beef demand increase, but it likely made a small contribution to the beef demand increase from 1998 to 1999.

3. Although new product development is important to revitalizing beef demand in the long run, it did not have a significant positive impact on beef demand during 1999.

   Most new products offered in 1999 were derived from either the Round or Chuck. Round prices were examined in detail and it's apparent the long-term decline in Round values, relative to the light Choice cutout value, continued unabated during 1999 providing evidence that consumer acceptance of new products was not responsible for 1999s demand increase.

   Ground beef values declined relative to the light Choice cutout value in the 1990s. Prices for 90% lean ground beef have stabilized, relative to the light Choice cutout value, since the mid-1990s. However, 90% lean ground beef values did not rise in 1999, compared to 1998. In contrast prices for fresh 50% lean ground beef increased relative to the light Choice cutout during 1999, especially late in the year, which could also explain a small portion of the 1999 beef demand rebound.

4. Data to test whether increasing consumer interest in high protein diets had a positive impact on beef demand were not available. As a result, it was not possible to ascertain what impact this factor had on beef demand during 1999.

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Technical Appendix

Almost Ideal Demand Model

The demand system employed in this study is the Almost Ideal Demand Model (AIDS) model (Deaton and Muellbauer, 1980) derived from the expenditure function

$$E(p,u) = \exp\left[a(p) + ub(p)\right]$$

where

$$a(p) = \ln P = \delta + \alpha' \ln p + (1/2) \ln p' \Gamma \ln p$$

and

$$b(p) = \prod_{j=1}^{n} p_j^{\beta_j}$$

The corresponding vector of share equations is

$$w = \alpha + \Gamma \ln p + \beta \ln(M / P)$$

where w denotes the N-vector of budget shares, p denotes the N-vector of prices, and M is total expenditure. Demand shifters are incorporated into the model by specifying (see Heien and Wessels, 1988; Piggott *et al.*, 1996; McGuirk *et al.*, 1995)

$$a_i = a_{io} + \sum_{k=1}^{K} r_{ik} DS_k \quad for\ i = 1,...,N$$

where K is the number of demand shifters, DS_k, includes seasonal, demographic, health information, and food safety variables.

The parameters to be estimated are the vectors α_{i0}, ρ_{ik}, β, and the matrix. Let ι denote the appropriate unit vector, then to satisfy homogeneity, adding-up, and symmetry the following restrictions must hold:

$$\iota'\alpha_0 = 1, \iota'\rho_k = 0, \iota'\Gamma = 0, \iota'\beta = 0, \Gamma' = \Gamma$$

The Linear Almost Ideal Demand Model (LAIDS) can approximate the AIDS demand model by replacing ln$P$ with Stone's price index, which is given by

$$\sum_{j=1}^{n} w_j \ln p_j$$

Moschini (1995) demonstrated that Stone's price index in the LAIDS model is not invariant to changes in units of measurement. Moreover, Alston, Chalfant, and Piggott (1999) have shown that the AIDS demand model is not invariant to units of measurement of the prices and quantities of the goods when the intercept term is augmented to incorporate the demand shifter variables. To accommodate these issues we use a corrected Stones Price Index in the LAIDS demand model, which can be obtained by dividing the prices and expenditure by their sample mean prior to taking a logarithmic transformation (Moschini, 1995; Moschini and Meilke, 1989).

Model Estimation

The demand model consisted of four equations, including beef, pork, poultry, and other consumption goods. The price of other consumption goods is calculated from the CPI, per capita personal consumption expenditures (deflated by the personal consumption expenditure implicit price deflator), and price indexes for beef, pork, and poultry (see Brester and Schroeder 1995, footnote 5). In preliminary analysis of the data, we estimated both the absolute price version of the Rotterdam demand model and the linear almost ideal demand system (LAIDS) model. The estimated price and income elasticities were similar between the two models. However, differences arose between the two models in the flexibility to implement demand shifters and the subsequent interpretation of their respective elasticities. Because the LAIDS model provided the most flexible approach with intuitive interpretations, it was chosen to represent the demand system.

Following typical demand system estimation procedures, the other goods equation was deleted from the system during the estimation process to avoid singularity in the covariance matrix. The parameters of the deleted equation were recovered using the adding up restrictions. The asymptotic standard errors, and hence the t-statistics, of the parameters from the deleted equation were possible to calculate because the parameters are linear combinations of random variables. The demand model was estimated using the iterative seemingly unrelated regression (SUR) estimator in SHAZAM (White, 1978). Symmetry, adding up, and homogeneity conditions were all imposed to make the models consistent with underlying economic theory.

To accommodate possible lagged effects on meat demand, both current and lagged values of the health index and the FSIS recall events were included in the model. Using a likelihood ratio test the null hypothesis that parameter estimates for lagged values of the health and FSIS recall variables were zero could not be rejected at the 0.05 level. As a result, the final model included price and expenditure variables, the percent of females in the labor force, the current period health, and food safety indices. In addition, tests for exogeneity of prices were conducted for each equation using the Hausman approach (Hausman, 1978). In the analysis lagged own prices, lagged quantities, income, quarterly dummies, health information, and meat recall variables were used as instruments. The null hypothesis that prices were exogenous could not be rejected at the 0.05 level.

Finally the demand model was tested for autocorrelation using the NL command in SHAZAM. The NL procedure is based on a Davidson-Fletcher-Powell algorithm with a correction for autocorrelation suggested by Pagan (1974). Autocorrelation up to the fourth-order in the demand model could not be rejected. The parameter estimates, autocorrelation coefficients, and regression statistics from estimation of the final demand model are reported in Appendix Table a1. The uncompensated price, income, and demand shifter (e.g., demographic, health, and food safety variables) elasticities are calculated as in McGuirk *et al.* (1995), who extended the formulas given by Green and Alston (1990) to accommodate demand shifters. Compensated elasticities, which are reported in Table 3, were calculated using the Slutsky equation.

Allocation of Demand Changes

This section describes how the proportion of beef demand changes each year were allocated to the independent variables in the model. The change in beef consumption was decomposed by the elasticity-weighted sum of the changes in pork, poultry, and other consumption good prices, as well as food safety, health, and demographics. Mathematically this can be represented by the total differential:

$$\frac{dq_1}{q_1} = \varepsilon_{11}\frac{dp_1}{p_1} + \varepsilon_{12}\frac{dp_2}{p_2} + \varepsilon_{13}\frac{dp_3}{p_3} + \varepsilon_{14}\frac{dp_4}{p_4} + \varepsilon_{1m}\frac{dm}{m} + \varepsilon_{1z_1}\frac{dz_1}{z_1} + \varepsilon_{1z_2}\frac{dz_2}{z_2} + \varepsilon_{1z_3}\frac{dz_3}{z_3} + u$$

where q_1 is beef consumption; p_1, p_2, p_3 and p_4 are beef, pork, poultry, and other consumption good prices; m is total per capita consumption expenditure; and z_1, z_2, and z_3 are food safety, health, and demographics variables. Above, ε_{11} is the uncompensated own-price elasticity for beef, while ε_{12} , ε_{13}, and ε_{14} are the uncompensated cross-price elasticities for pork, poultry, and other consumption goods. The elasticity ε_{1m}, is total per capita consumption expenditure, and ε_{iz} (i=1,2,3) are demand shifter elasticities. The notation $dq_1 \approx \Delta q_1$, for example, represents the differential change in beef consumption.

Several steps were taken to empirically determine changes in beef demand attributable to the independent variables. First, assume a shift in demand from D_0 to D_t (see Figure a1). Let (p_0,q_0) and (p_t,q_t) represent equilibrium beef prices in the current period and the subsequent period, respectively. Then p^* is the price on the demand curve D_t, if quantity is held constant at q_0. From point (p_t,q_t) the price p^* is approximated as $p^* = p_t + \Delta p = p_t + \Delta q * f * p_t / q_t$. Here Δp follows from the flexibility relationship $f \approx (\Delta p/\Delta q)(q/p)$ and $\Delta q = (q_t - q_0)$. The price flexibility f is calculated by inverting the matrix of substitution elasticities. The vertical shift in price due a shift in demand from D_0 to D_t is then defined as $\Delta p^* = p_0 - p^*$. Similarly, a horizontal shift in quantity due to a shift in demand from D_0 to D_t is constructed.

Second, applying the equation of the total differential defined above, the shift in beef consumption (holding beef price constant, $\Delta p_1=0$) is attributed to a component made up of changes in total per capita consumption expenditure, meat recall, health, and demographics variables plus a component that is caused by other factors (i.e., unexplained by the model). To retain consistency with indices in previous studies, the changes in beef consumption are translated to changes in beef price using the uncompensated own-price elasticity for beef. In this way, percentage vertical shifts attributable to changes in each demand determinant can be calculated for each time period. See Table a2 for the elasticities used in the allocation exercise, which include the uncompensated or Marshallian elasticities.

Figure A1. Shift in Beef Demand

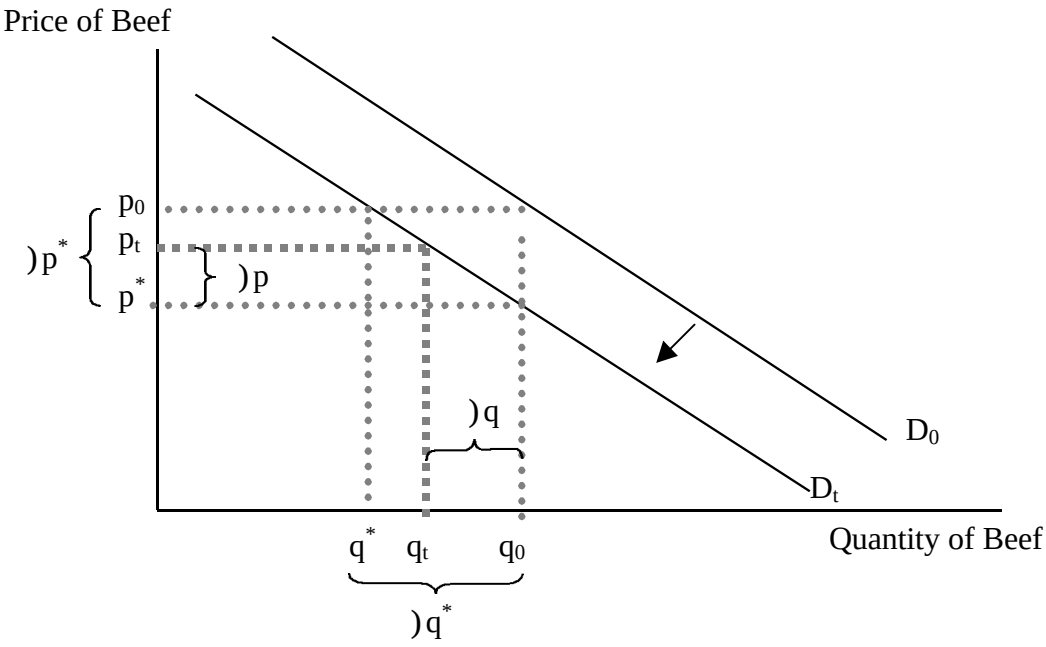

Table A1. Coefficient Estimates of LAIDS Demand Model, Quarterly Data 1982-1998.

	Demand Equation:			
Dependent Variable:	Beef	Pork	Poultry	Other Goods
Beef Price	1.33E-03	1.33E-04	5.12E-05	-1.52E-03
	(3.53)	(1.05)	(.42)	(-3.64)
Pork Price	1.33E-04	8.87E-04	-2.97E-06	-1.02E-03
	(1.05)	(9.50)	(-.05)	(-6.05)
Poultry Price	5.12E-05	-2.97E-06	1.16E-03	-1.21E-03
	(.42)	(-.05)	(14.47)	(-7.66)
Other Goods Price	-1.52E-03	-1.02E-03	-1.21E-03	3.74E-03
	(-3.64)	(-6.05)	(-7.66)	(7.87)
Expenditures	-3.42E-04	-4.81E-04	-1.72E-03	2.55E-03
	(-.58)	(-1.28)	(-6.26)	(3.40)
Beef Recalls	-1.04E-05	-5.83E-06	-2.18E-07	1.64E-05
	(-3.09)	(-2.46)	(-.14)	(3.72)
Pork Recalls	1.83E-08	2.64E-06	7.55E-07	-3.42E-06
	(.005)	(.98)	(.40)	(-.68)
Poultry Recalls	1.03E-06	2.43E-06	-2.18E-06	-1.28E-06
	(.20)	(.64)	(-.86)	(-.18)
Health Index	-1.55E-07	1.78E-07	1.94E-07	-2.17E-07
	(-.65)	(1.47)	(2.13)	(-.77)
Female Labor Force	-9.11E-05	-4.57E-05	9.86E-06	1.27E-04
	(-2.77)	(-2.43)	(.75)	(3.16)
Quarter 1 Dummy	-4.38E-05	-1.63E-04	-1.48E-04	3.54E-04
	(-1.84)	(-9.99)	(-13.68)	(11.50)
Quarter 2 Dummy	1.16E-04	-1.87E-04	-9.60E-05	1.67E-04
	(6.00)	(-13.46)	(-10.82)	(6.55)
Quarter 3 Dummy	1.94E-04	-1.34E-04	-8.34E-05	2.35E-05
	(10.82)	(-10.23)	(-10.01)	(.99)
Intercept	8.51E-03	4.24E-03	5.46E-04	0.9867
	(4.55)	(4.22)	(.77)	(4.41)
R-square	0.84	0.89	0.78	0.89

t-statistics of the coefficient estimates are in parentheses; autocorrelation coefficients with t-statistics in parenthesis are ρ_1= 0.36379 (4.9553), ρ_2 = 0.16134 (2.2671), ρ_3 = 7.06E-02 (1.0161), and ρ_4 = 0.23231 (3.5584); log-likelihood value is 1812.61; Theil's Information Inaccuracy Statistic is .0013.

Table A2. Estimated Uncompensated Elasticities for Meat Demand Model, Quarterly Data 1982-1998[a]

	Quantity of:			
With Respect to:	Beef	Pork	Poultry	Other Goods
Beef Price	-0.61133	0.075191	0.046555	-0.00153
Pork Price	0.039012	-0.50419	0.00009	-0.00103
Poultry Price	0.015072	-0.00133	-0.05235	-0.00122
Other Goods Price	-0.34459	-0.30272	0.40685	-0.99877
Expenditure	0.900144	0.731395	-0.40259	1.002559
Beef Recalls	-0.00652	-0.00699	-0.00038	0.000036
Pork Recalls	0.000009	0.002602	0.001086	-6E-06
Poultry Recalls	0.000478	0.002155	-0.00282	-2E-06
Health Information	-0.05353	0.11757	0.187117	-0.00026
Female Labor Force	-1.51151	-1.4502	0.456903	0.00726

[a] Elasticities are calculated at the mean values of the explanatory variables. Mean expenditure shares for beef, pork, poultry, and other goods are 0.34249E-02, 0.17907E-02, 0.12263E-02, and 0.99356, respectively.