ANALYSIS OF DEMAND FOR BEEF, PORK, LAMB AND BROILERS: IMPLICATIONS FOR THE FUTURE

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Introduction

The interaction of demand and supply determines price for the meats. In the short run, such as within a year, demand does not typically change enough to be the primary force in price changes. But over time, structural or long-range changes in the level of demand can be a dominant influence on supply and on the economic viability of the industry.

In the livestock and poultry sectors, the demand for the product at the producer level is a derived demand. Any change in demand at the retail-consumer level will be transfered back down to the producer level in the form of a price change. In the short run, the transfer can be influenced by changes in the farm-retail price spread or operating margin of the processing institutions, but the impact will eventually be felt at the producer level in the form of price adjustments. The level of demand thus helps to determine the long-range price outlook and provides the foundation upon which long-range investment decisions must be based.

Objectives

The overall objective of this manuscript is to describe and analyze the demand for the meats and to trace the implications of changes in demand to the industry sector. Specific objectives include:

1. To examine what has happened to demand for the meats during the 1960-88 period;
2. To relate the documented changes in demand to changes in industry structure and to related adjustments in industry operating procedures; and
3. To infer the implications of the current situation and potential changes in demand to the outlook for the meat industry in the 1990s.

The Historical Perspective

Since 1960, the red meat industry has recorded significant changes in size and production potential. Figure 1 records inventory numbers for cattle, hogs, and sheep. Dramatic reductions in numbers have been recorded for cattle and sheep, and the trend in hog numbers has been down, especially in recent years.

Inventory numbers establish the production potential for each of the subsectors. Production levels, in turn, dictate the level of consumption and market share. After accounting for the net influence of exports and imports, consumption will equal product availability for any perishable product.

Product availability has not moved in a 1:1 ratio with the total inventories. This has been especially true in beef where the levels of production for a given herd size have changed significantly across the 1970s and 1980s. Figure 2 documents, showing the level of commercial production plotted against January 1 total cattle inventories.

A higher percentage of the January 1 inventories is being fed in recent years, and the yield per head has increased with changes in cattle type. Record high average slaughter weights were being recorded in late 1988. Production from a herd below 100 million is now paralleling production levels from the late 1970s when the herd was significantly larger.

Figure 1. Inventory Levels for Cattle, Hogs, and Sheep, 1960-88

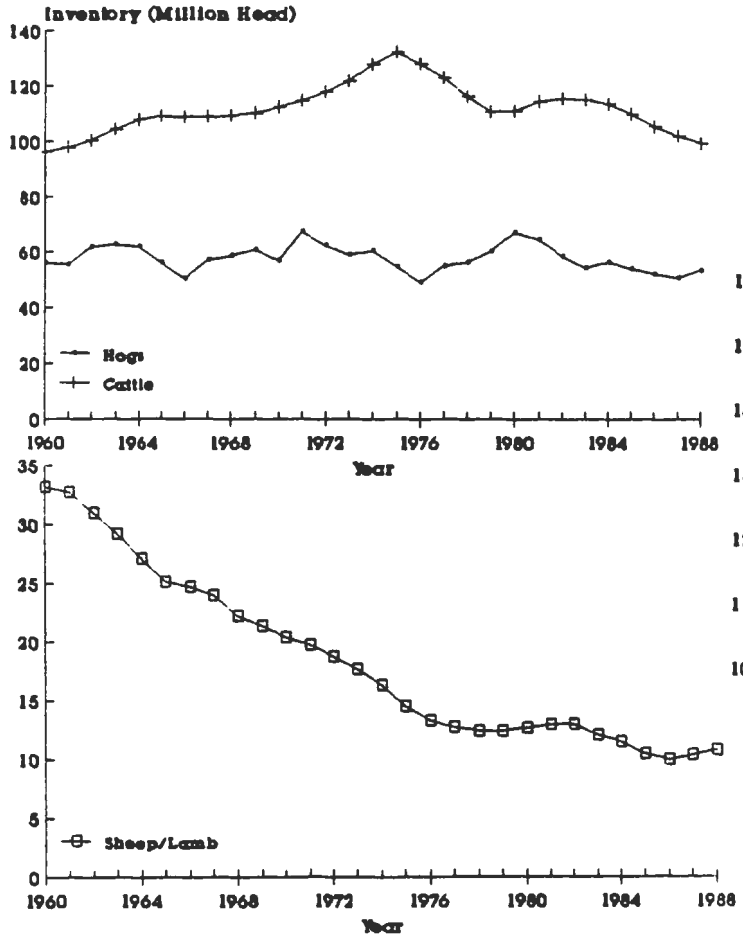
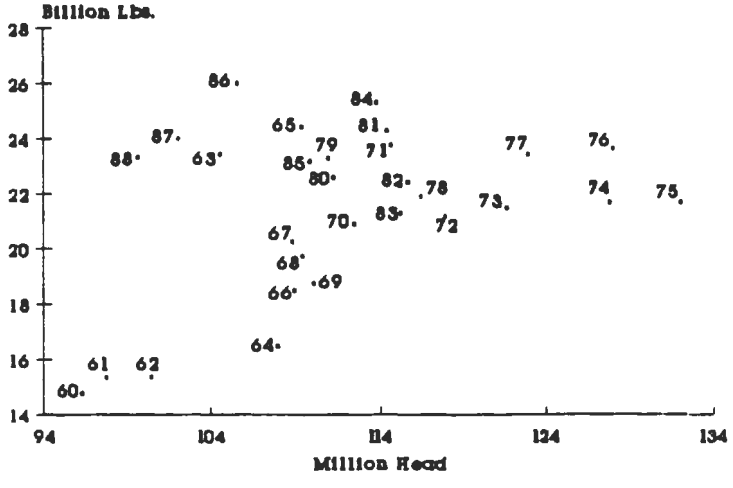


Figure 2. Commercial Beef Production Related to January 1 Inventories



Figures 3 and 4 show a similar scatter plot for hogs and sheep respectively. The changes are less dramatic than in cattle, but are significant, especially in hogs. Year-round production and other progressive production practices have increased pork production per sow per year. In sheep, increased twinning, the related higher lambing percentages, and breeding for increased production have boosted commercial production.

Figure 3. Commercial Hog Production Related to December 1 Inventories

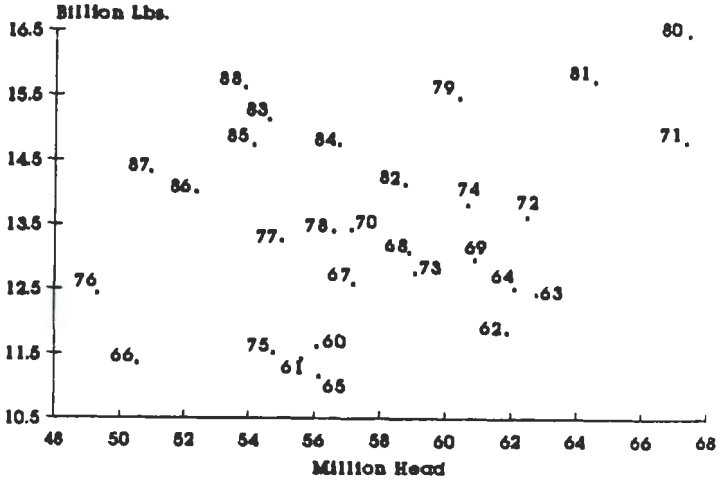
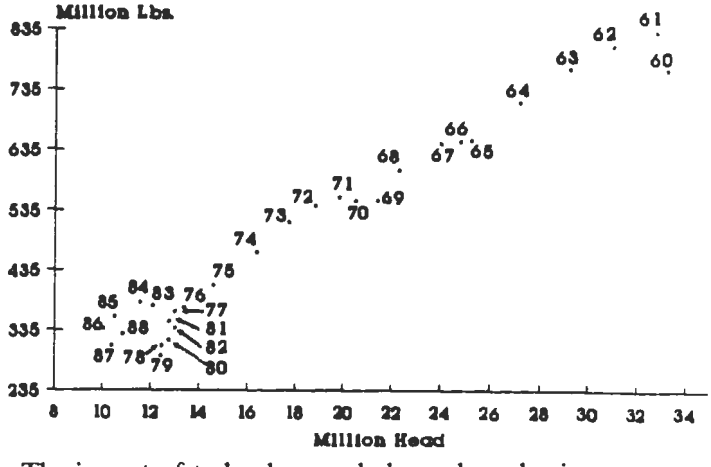
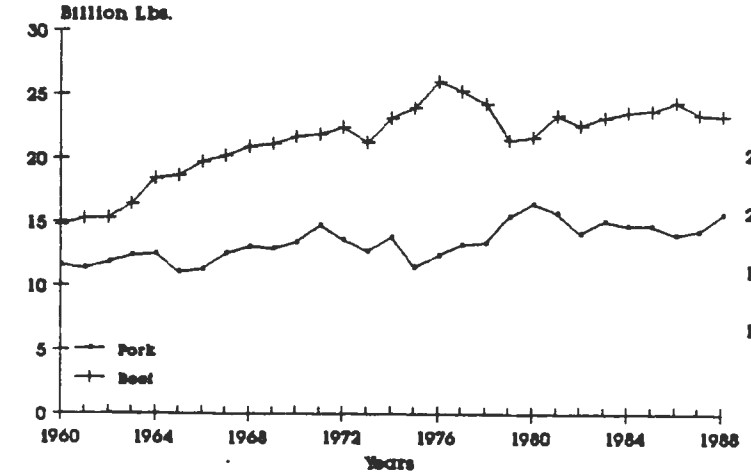


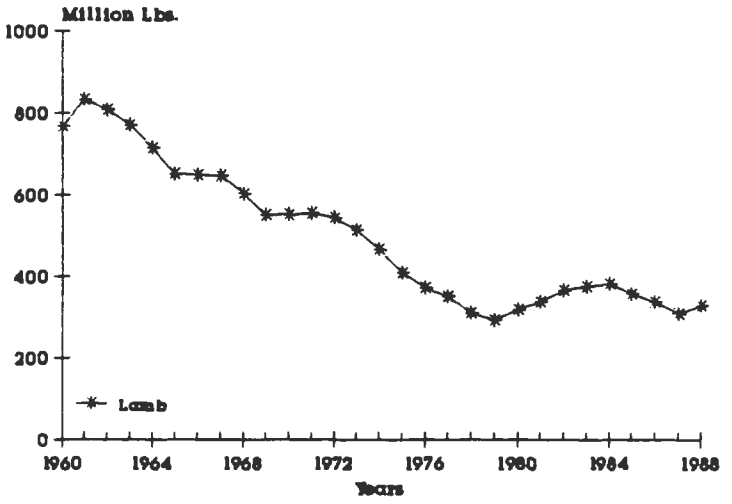
Figure 4. Commercial Lamb/Mutton Production Related January 1 Inventories



The impact of technology and changed production practices have thus boosted production across the 1960-88 period. Figure 5 shows patterns for beef, pork, and lamb/mutton. Inventory declines have been too significant in the sheep subsector to be offset by increased efficiency, but the 1980s records stable to higher beef production levels in spite of continued herd reductions. The pattern for pork is more mixed, but periods of sharp reductions in production are apparent.

Figure 5. Production Levels for Beef, Pork, and Lamb/Mutton, 1960-88

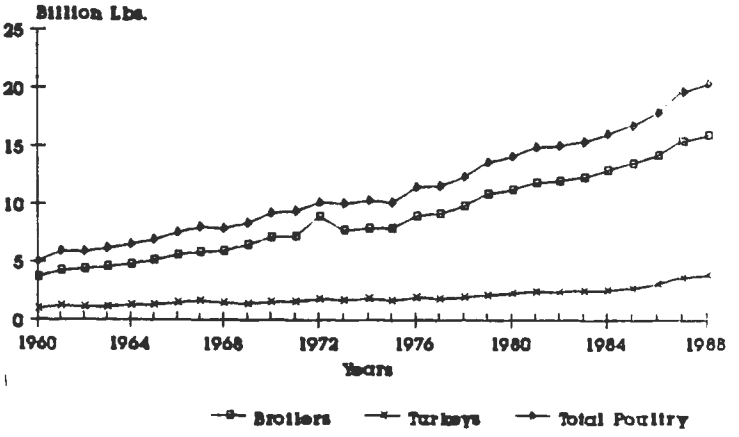




The size of the red meat industry has changed significantly during the past two decades. Inventory numbers and the potential production base are down. Such a change will bring an inevitable change in market share for the red meats unless competing meats have experienced similar declines.

Figure 6 shows production levels across the 1960-88 period for broilers, turkey, and total poultry. It is apparent that the trend in poultry production has been up, especially in recent years where dramatic increases have been recorded.

Figure 6. Production Levels for Broilers, Turkeys and Total Poultry, 1960-88



Given the documented differences in production patterns, the line of reasoning introduced earlier suggests market shares have changed significantly. The most effective way to document those changes is to examine what has happened to per capita consumption. For perishable products, per capita consumption measures per capita supplies (production plus the net from imports and exports) and eliminates the need to deal with changes in population.

Figure 7 documents per capita consumption in retail weight equivalents for beef, pork, lamb/mutton, broilers and turkeys. The direction of trend for the red meats is different than for the poultry products, and the differences are being accentuated in recent years.

In Figure 8, total meat consumption (red meats plus poultry) is shown with total red meats and total poultry. Across the 1960-88 period, total red meat consumption has been relatively stable with some evidence of a slight downward trend starting in the mid-1970s. For poultry, the picture is different. A positive trend is apparent, and the rate of growth started to increase in the mid-1970s.

Figure 7. Per Capita Consumption of Beef, Pork, Lamb/Mutton, Broilers, and Turkeys, 1960-88

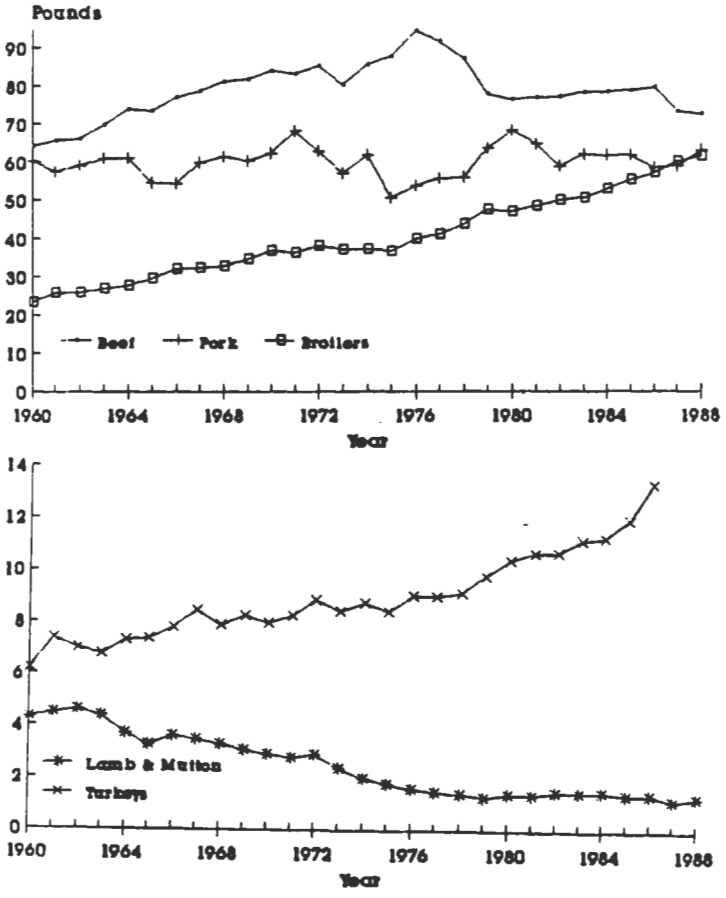
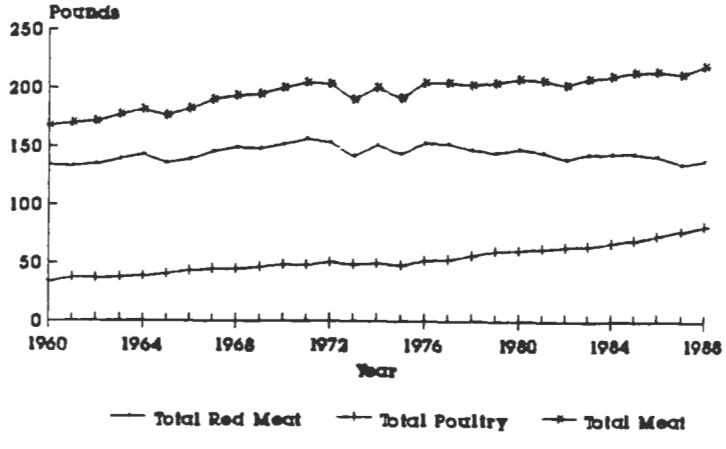


Figure 8. Per Capita Consumption of Total Meat, Total Red Meat, and Total Poultry, 1960-88



It is a tautology, as suggested above, that per capita consumption will parallel per capita supplies. Examination of changes in per capita consumption therefore involves looking at changes in per capita supplies, and raises the issue of why the changes in production or supply levels have occurred.

Significant shifts in the mix of per capita consumption of meats have occurred. Such shifts suggest resources have been added to poultry production while the resources committed to red meat production have been constant or have declined. Either changes in costs of production (reflecting technology), changes in demand (possibly reflecting preference changes), or both are possible reasons for the adjustments during the 1960-88 period.

Basics of Demand

Before examining the demand for the specific meats, it is important that we understand the nature of the impact of changes in demand at the producer level. The demand at the producer level is a *derived demand*. Accordingly, the price at the producer level is a *derived price*. Understanding of that framework is a necessary condition to understanding the producer-level implications of changes in demand at the consumer level.

The most dramatic developments have occurred in the beef sector, and beef will be used to illustrate. Figure 9 demonstrates, showing an illustrative demand curve or demand schedule at retail and a related demand curve at the producer level. The difference in price at retail and the price at the producer level in terms of retail value equivalent is generally called a *price spread*. It is not equal to but does encompass the operating margins of the middlemen involved in processing the live animal into the consumer-ready product.

In simplistic terms, the price spread is $P_s = P_r - P_f$ where:

P_r = price at retail,
P_f = price at farm level, and
P_s = the price spread.

In calculating price spreads, the farm-level price is usually expressed in retail equivalent value to provide a "common denominator" for use in the calculations. If P_r cannot be moved up over time at essentially the same short-run supply or quantity level, any increase in the middlemen's operating costs over time will exert downward pressure on P_f. The packers, breakers, and retailers must either accept a smaller return on investment or pass the im-

Figure 9. Demonstration of the Derived Demand Concept for the Beef Sector

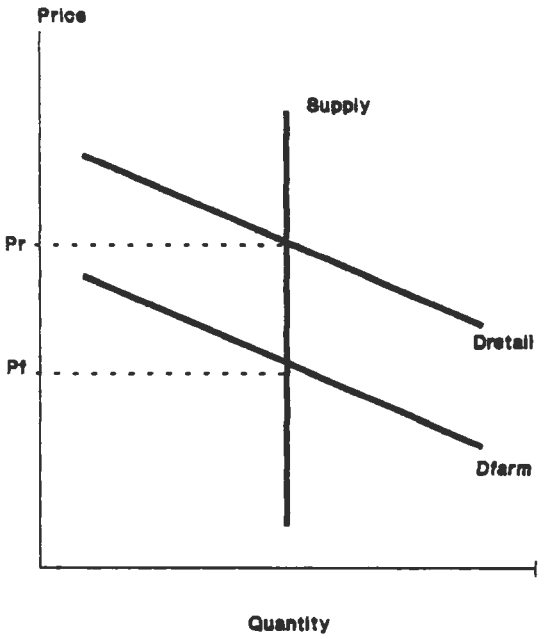
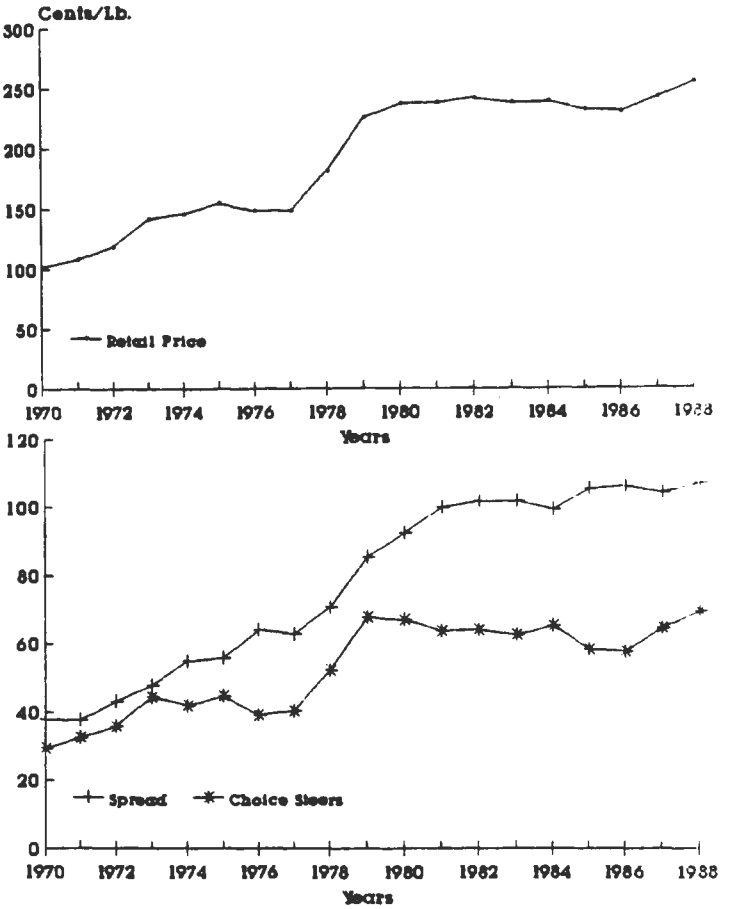


Figure 10. Retail Beef Prices, Farm-Retail Price Spreads, and Choice Steer Prices, Omaha, 1970-88



pact of the increased costs back down to the producer level in the form of lower livestock prices.

Focusing attention on the 1970-88 period, Figure 10 demonstrates the important relationships. From 1979 through 1988, the retail price of Choice beef has shown little change. Across that same time period, the farm-retail price spread increased significantly, with large increases in the late 1970s and early 1980s when the rate of price inflation periodically reached double digit levels. Choice steers at Omaha moved lower from 1979 through 1986 before recovering in 1987 and 1988. Decreased supplies pushed the retail prices higher during 1987 and 1988. Prices of live cattle increased even more. Price spreads narrowed as packers were forced to compete for reduced cattle supplies.

In looking at Figure 10, it is important to keep in mind that the live cattle price and the price spread should not sum to the retail price. As suggested above, the price spread is calculated using a farm level value expressed (after dressing percentage conversions, etc.) in *retail-level equivalents*. The Choice steer at Omaha price series is shown to demonstrate that expanding price spreads, which tend to reflect increased killing and processing costs, are accompanied by lower live cattle prices when the retail price is relatively constant as it was from 1979 through 1986.

Before leaving this area, it is useful to briefly look at why the producer level will bear the brunt of the pressures of expanding processing costs. The development to this point suggests that the inability to pass higher prices up to the consumer will result in lower live cattle prices, not reduced operating margins at the middleman level. The reason is the difference in economic structure at the two levels of the continuum that runs from the producer to the consumer.

At the producing level, there are many small producers. No one producer is large enough to exert a significant influence on price via their actions, and the producer operates as a *price taker*. On any particular day, the producer "takes" the price being discovered in the auction market or the direct bids from buyers where the bids are being determined at a broader and more nearly aggregate market level. The cattle feeder can resist lower bids on any particular day, but must soon sell the cattle in a market where the short-run price direction is being deter-

mined via what is happening in the carcass market, the boxed beef market, and in the prices being discovered at the Chicago Mercantile Exchange. There is no opportunity to significantly influence price levels, and no assurances of securing a margin above costs at the producer level. The economic situation at the producer level approaches the textbook conditions of *pure competition.*

In the processing sector, the economic structure is totally different. Firms are large and possess the market power necessary to influence price or other terms of trade. The structure is called *oligopoly* (few, large sellers) or *oligoposony* (few, large buyers). In this type of structure, the firm *will* be able to pass on the impact of increasing costs and secure a margin above costs or the resources will be diverted to other uses.

This topic will be treated in more detail later, but it is clear that the impact of expanding margins *has* been passed down to producers, at least partially. During the late 1970s and 1980s, the processing sector of the beef industry has seen an unprecedented consolidation and increase in the level of concentration as fewer, large firms have emerged to dominate the industry at the killing, breaking, and processing levels.

> **Demand at the producer level is a derived demand. If the impact of expanding processing costs will not be accepted by consumers in the form of higher prices, the pressure must be relieved in some other way. The firms involved in the slaughter and processing functions must either reduce operating costs via technology or seek to buy their raw material (live cattle) at lower prices. The evidence presented suggests a significant part of the pressure of inflated operating costs in the beef subsector across the past decade has been relieved in the form of downward pressure on live cattle prices.**

Demand for Beef

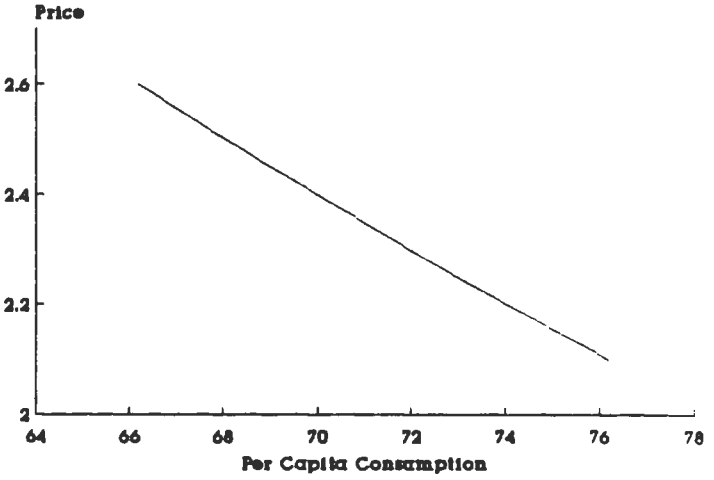
The demand for any product such as beef is a schedule of the quantities that will be taken by consumers at alternative prices. At a particular point in time and for given preference patterns, income levels, and prices of other products, the typical consumer will take more of the product only at lower prices. Table 1 illustrates, relating the price of Choice beef at retail (a composite price for different beef cuts) to per capita consumption levels.

Table 1. A Schedule of Quantities Taken by a Typical Consumer at Alternative Prices

Price ($/lb.)	Quantity (lbs. Retail Weight)
$2.60	66.2
2.50	68.0
2.40	70.0
2.30	71.9
2.20	74.0
2.10	76.2

Figure 11 shows a plot of the hypothetical "schedule" from Table 1. For a given preference pattern, income level, and set of alternative product prices, the typical consumer will move along the *demand curve* shown in Figure 11 and adjust quantities as prices change. Thus, as prices change, the *quantity demanded* changes but there is *no change in the demand for beef until the entire schedule, the entire curve, shifts.*

Figure 11. A Price-Quantity Demand Schedule or Demand Curve



The distinction between a *change in quantity demanded* and a *change in demand,* when the entire curve shifts, is extremely important. Over time, if there is no willingness of the consumer to pay increased prices for a constant or increasing quantity, there is no increase in demand being registered. Under these conditions, there will be only limited ability to pass the burden of increased processing costs up to consumers. A higher price would be paid by the consumer only if the quantity being offered is reduced. But reductions in quantity mean the level of the industry output is being reduced, and that will eventually mean resources being diverted to other uses -- which is what we saw in the beef industry from 1976 through 1987.

The situation would be much worse, of course, if the demand curve is shifting down. If consumers will take a constant or even reduced quantity only at lower prices, then demand is decreasing and the entire "curve" shifts down. Such shifts will accentuate the problems of passing any of the burden of increased processing costs up to consumers, and will intensify the pressure on the processing sector to reduce costs and/or buy livestock at lower prices.

> **The ability to pass the burden of increased processing costs up to consumers will vary directly with what is happening to the *level* of demand. If the entire demand curve is not shifting up via increases in demand, the consumer will pay a higher price for beef only if offered a reduced quantity. If the demand curve is shifting down, the difficulties are compounded. Consumers will be willing to pay less for a constant or even reduced quantity, and the pressure back down toward the producing level will be intensified.**

With this bit of background for beef, the price-quantity relationships can be examined. We start with Table 2 which shows per capita consumption and retail Choice beef prices in both *nominal* and *deflated* terms. The nominal prices are the prices observed each year, and the focus of attention will initially be on the nominal prices.

Table 2. Per Capita Consumption and Price of Choice Beef at Retail, Actual and Deflated (CPI, 1982-84=100), 1970-1988

Year	Per Capita Consumption (lbs. retail weight)	Retail Price (cents/lb.)	Deflated Retail Price (cents/lb.)
1970	84.4	98.6	262.0
71	83.7	104.3	267.0
72	85.5	113.8	283.8
73	80.5	142.1	319.8
74	85.4	146.3	296.7
75	88.0	154.8	287.7
76	94.2	148.2	260.4
77	91.4	148.4	244.9
78	87.2	181.9	278.9
79	78.0	226.3	311.8
80	76.4	237.6	288.4
81	77.1	238.7	262.5
82	76.8	242.5	251.3
83	78.2	238.1	239.0
84	78.1	239.6	231.1
85	78.8	232.6	216.3
86	78.4	230.7	210.4
87	73.4	242.5	213.4
88	72.7	254.7	215.1

The nominal prices in recent years (since 1979) have been essentially constant. Consumers would not accept and pay price increases for essentially a constant per capita supply. That suggests an inability to pass the burden of increasing processing costs up to the consumer, and earlier presentations suggested that costs did increase significantly across the 1979-1988 time period.

Looking at nominal prices can be confusing. It is impossible to separate the influence of changing price levels over time (as measured by the Consumer Price Index, for example) and the influence of changes in underlying economic forces (shifts in demand, for example) as nominal prices are examined. A commonly used solution is to adjust the nominal prices for the influence of inflation. The deflated prices are shown in Table 2.

With the influence of price-level changes removed, the yearly prices can be legitimately compared. From 1979 through the 1987-88 period, the deflated prices had to decline by over 30 percent for the typical consumer to be willing to take essentially the same per capita supply. Since processors' operating costs (labor, packaging, refrigeration, transportation, etc.) will tend to move up roughly parallel with the level of price inflation, it is clear that the increased costs were not being passed up to consumers during the 1979-88 period. Technological change during such a brief time period will not be sufficient to offset expanded processing costs. Given developments to this point, therefore, we would expect to see the pressures of expanded processor costs being evidenced in the form of lower cattle prices.

Figure 12 traces the deflated prices of Choice fed steers at Omaha and 600-700 pound feeder steers at Kansas City. The declines in the inflation-adjusted prices of Choice beef at retail are clearly registered in the form of lower inflation-adjusted prices for fed cattle and feeder steers. There is no suggestion that the changes are 1:1. Other forces, such as the price of hogs or the cost of corn, influence live cattle prices. But the relationship is clearly present, and it traces back to the apparent problems at the consumer level.

Figure 13 helps to document the implicit problems on the demand side. A scatter plot for per capita consumption and deflated retail Choice beef prices is shown back to 1960. During the 1960s and 1970s, it is easy to find year-to-year changes that show increased quantities being moved into consumption at higher prices. Demand for beef was *increasing* during that period, and the industry was a growth industry. Feedlot capacity was being built, and the herd moved up to the record 132 million head in 1975.

Observation suggests the pattern reversed in 1979, with a tendency toward lower real or deflated prices at essentially constant per capita supplies through 1986. In 1987 and again in 1988, quantity declined

Figure 12. Deflated Prices (1982–84 = 100), Choice Steers, Omaha, and Feeder Steers, Kansas City, 1970–88

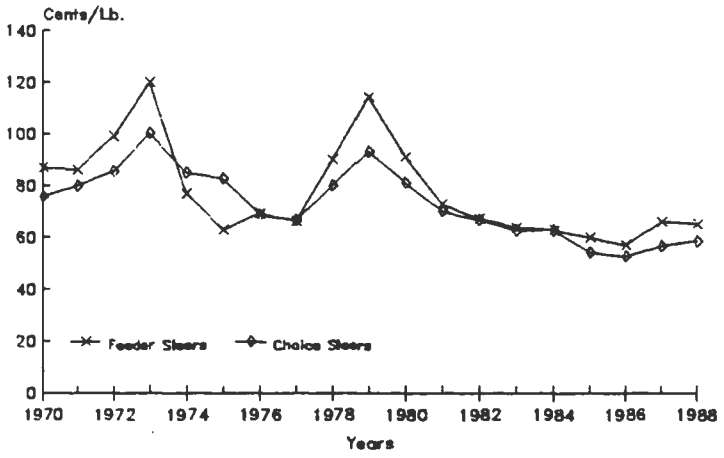
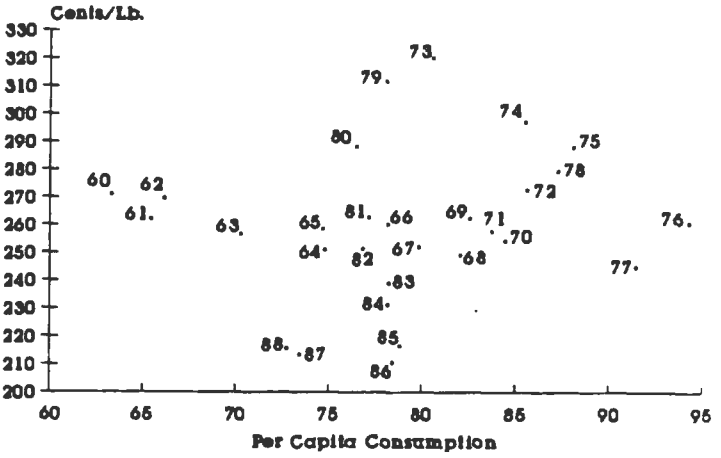


Figure 13. Per Capita Consumption and Deflated Retail Prices for Beef (1982-84=100), 1960-88



as the impact of the prolonged herd liquidation finally started to offset the impact of feeding a higher percentage of the herd and moving to cattle types that allowed increases in average slaughter weights and increases in yield per head.

During 1987 and again in 1988, the deflated retail beef prices recorded small year-to-year increases. Does this mean the problems on the demand side are being solved or even reversed? A closer look at the 1987-88 period will clarify whether demand did in fact change. It will establish a base that will be useful later in the manuscript when measure of demand changes, such as changes in the percent of income spent on beef, are discussed.

The demand for any product has a property called *elasticity*. The so-called "own price elasticity of demand" is a measure of the relationship between percentage changes in price and quantity as movement along a demand curve (due to changes in supply) are recorded. Specifically, demand elasticity is defined as the ratio of percent change in quantity over the percent change in price. For beef, recent research suggests the own-price elasticity of demand is around -.67.

An elasticity coefficient of -.67 means, for example, that a 2 percent change in quantity will result in a 3 percent change in price in the opposite direction. If quantity is decreased by 2 percent, to continue the development, and price does not increase or increases less than 3 percent, then the price-quantity data would suggest that demand has *decreased*. Conversely, if a 2 percent decrease in quantity is met by a price increase significantly larger than 3 percent, then the evidence suggests that demand has *increased*. Clearly, no conclusions about increases or decreases in demand can be drawn from looking at either price or quantity alone. *Both price and quantity* have to be examined to determine what is happening to demand.

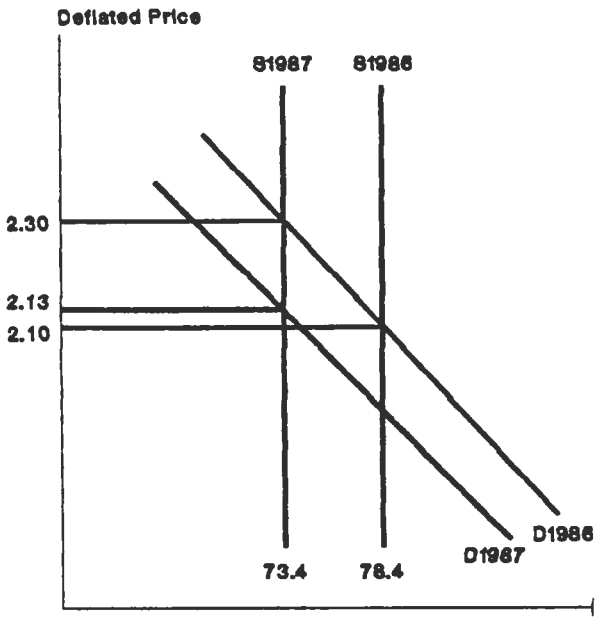
From 1986 to 1987, per capita consumption of beef declined from 78.4 to 73.4 pounds as the level of production declined under the pressure of prolonged herd liquidation. The decline was a percentage change of -6.38 percent. If the demand elasticity for beef is around -.67, the deflated retail Choice beef price would have to increase by 9.52 percent (-6.38 divided by -.67) to stay on the same demand curve and still be operating at the 1986 level of demand.

After adjusting for the influence of price inflation, the retail price actually increased from $2.10 in 1986 to $2.13 in 1987, a 1.4 percent increase. With a price increase much smaller than the 9.52 percent needed to hold at least the same level of demand, the evidence suggests that demand for beef declined again from 1986 to 1987.

Figure 14 demonstrates what apparently happened. To remain on the same demand curve or level of demand that apparently prevailed in 1986, the 1987 inflation-adjusted price would have had to be around $2.30, not the $2.13 that was actually recorded. It appears, therefore, that the level of demand in 1987 was below that of 1986, and another year-to-year decrease in demand was recorded.

To review this important point, the price of $2.30 shown in Figure 14 would have been the price required to balance the 1987 supply or quantity offered with demand *at the 1986 level of demand*. But consumers were not willing to pay the $2.30 on average, and actually took the reduced offerings during 1987 at a lower price of $2.13. *It is conceptually and totally incorrect to observe the higher prices in 1987 and conclude that demand has increased.* A reduction in per capita supplies of over 6 percent was

Figure 14. Demonstration of Shifts in Demand for Beef, 1986 and 1987



required to generate the 1.4 percent increase in price, and the pattern of contracting supplies and a contracting industry was continued.

The pattern that developed in 1988 showed signs of improvement. Per capita consumption was down slightly from 1987, and the inflation adjusted price was up. For 1988, it would be possible to develop support for the position that the declines seen since 1979 are drawing to a close, and the situation is starting to consolidate. The 1987 to 1988 change shows a 1.0 percent reduction in per capita supplies, from 73.4 to 72.7 pounds. Price increased 1.0 percent, from $2.13 to $2.15 per pound after adjusting for inflation. Using the -.67 elasticity coefficient, the price in 1988 would have had to be at $2.16 per pound to stay on the same demand curve as that observed for 1987.

Before leaving this simplistic look at beef demand, it is important to recognize that the analysis to this point has not determined *why* the decreases in demand occurred through 1987. Demand will shift down or decrease if preference patterns turn negative, if the prices of competing products fall, or if there is a negative relationship between advances in income and a willingness to spend those advances on a particular product. More detailed analysis of the "why" will be included later, but it is clear at this point that reductions have occurred.

It appears that decreases in demand for beef that started in the late 1970s have been a primary factor in forcing livestock prices lower and continuing the herd liquidation and disinvestment. In the face of decreases in demand, consumers would not pay higher prices and the pressures of increased processor costs were felt in a significant way at the producer level. The first signs of consolidation and improvement since 1979 occurred in 1988, and the outlook for the 1990s for the cattle sector will depend in a major way on whether improvement in demand can be continued.

Demand for Pork

The situation for pork can be developed drawing on the more detailed discussions for beef. Demand for hogs is a derived demand, and the tendency toward pressure on live-hog prices if processors' costs increase is still present. If demand at retail is static or decreasing, the pressure at the producer level will be accentuated.

Figure 15 shows a scatter plot of deflated retail pork prices and per capita consumption from 1960 through 1988, the parallel to the plot for beef in Figure 13. Table 3 focuses on the price-quantity relationships between 1970 and 1988, and shows both nominal and deflated prices.

In beef, there were indications during 1988 that the demand situation was starting to stabilize and possibly turn more positive. In pork, there is strong evidence that improvement started in 1987.

Both Figure 15 and Table 3 confirm very positive developments during 1987. An increased per capita supply was moved into consumption at higher deflated prices -- a sure sign of *increased demand.* The positive performance was repeated in 1988. Quantities increased significantly, but the price decrease was less than the elasticity framework would suggest.

Figure 16 provides a demonstration for pork comparable to that in Figure 14 for beef. If the industry had been facing the same demand curve in 1988 as in 1987, the increase in per capita supplies from 59.1 to 63.1 pounds, a 6.76 percent increase, would have brought a decline in deflated price from $1.66 in 1987 to $1.49 in 1988. A demand elasticity of -.67 is used here, suggesting the 6.9 percent increase in quantity would bring a price decline of over 10 percent *if consumers were operating on the same demand curve as for 1987.* The actual deflated price for 1988 was around $1.55, a decline of only 6.51 percent.

It appears, therefore, that the demand for pork increased again in 1988 if elasticity of demand is approximately -.67. Once again, we see the fallacy of trying to draw conclusions about demand by look-

Figure 15. Per Capita Consumption and Deflated Retail Prices for Pork (1982-84=100), 1960-88

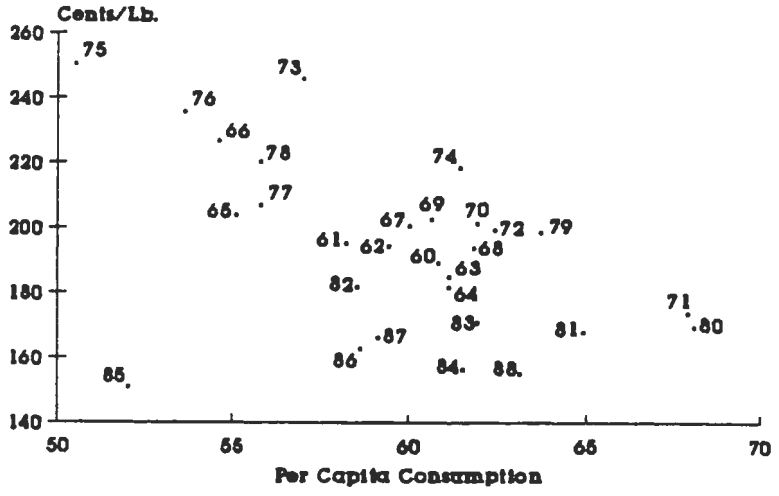


Figure 16. Demonstration of Shifts in Demand for Pork, 1987 and 1988

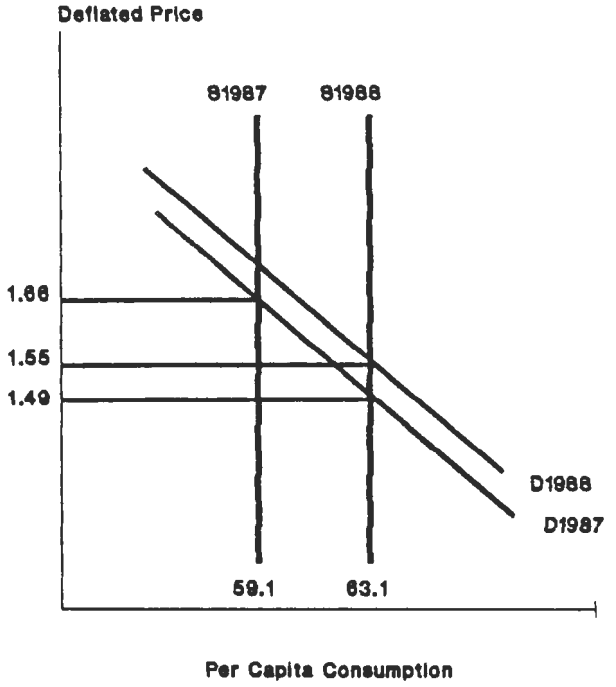


Table 3. Per Capita Consumption and Price of Pork at Retail, Actual and Deflated (CPI, 1982-84=100), 1970-1988

Year	Per Capita Consumption (lbs. retail weight)	Retail Price (cents/lb.)	Deflated Retail Price (cents/lb.)
1970	61.9	78.0	199.4
71	67.9	70.3	172.4
72	62.4	83.2	197.7
73	57.0	109.2	245.8
74	61.4	107.8	218.6
75	50.5	134.6	250.1
76	53.6	134.0	235.4
77	55.8	125.4	207.0
78	55.8	143.6	220.1
79	63.7	144.1	198.6
80	68.1	139.4	169.2
81	64.9	152.4	167.6
82	58.5	175.4	181.7
83	61.9	169.8	170.5
84	61.5	162.0	156.3
85	62.0	162.0	150.6
86	58.6	178.4	162.7
87	59.1	188.4	165.8
88	63.1	183.4	155.0

ing only at price changes. Both nominal and deflated prices were lower in 1988 than in 1987, *but looking at performance of both price and quantity indicates that demand actually increased.* The consumer accepted expanded per capita supplies without the decrease in price that would have been required if the 1987 level of demand had still been in effect.

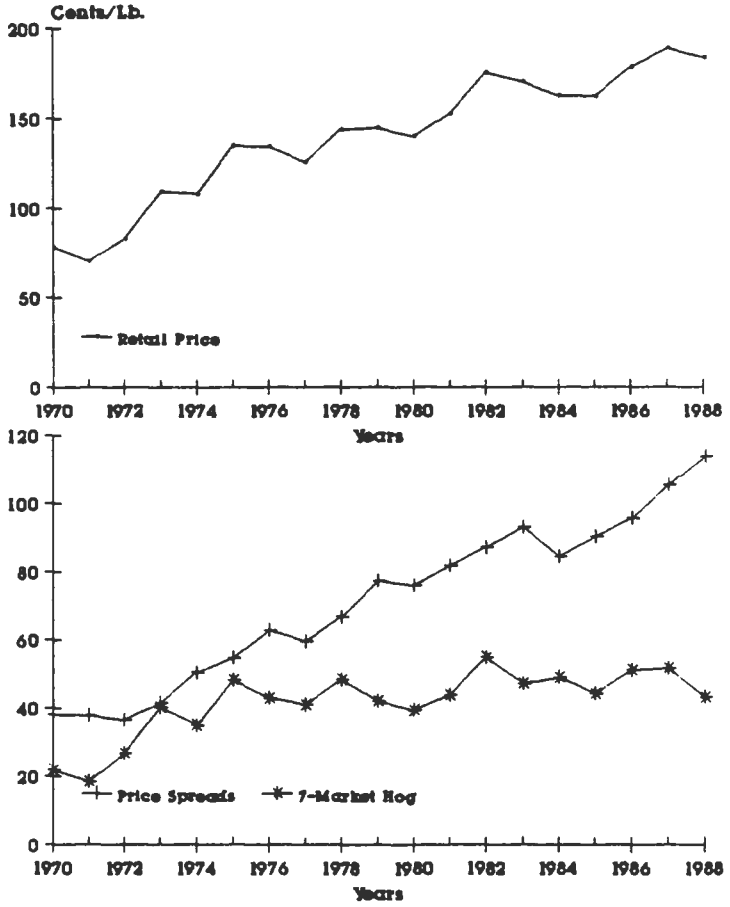
Given the evidence of increasing demand for pork, the earlier developments suggest that some of the pressure on live hog prices should have been relieved in 1987 and 1988. Consumers were willing to accept higher prices, and any increase in middleman or processor costs could have been passed, at least partly, up to the consumer level.

Figure 17 records retail pork prices, the farm-retail price spread, and live hog prices for 7 major terminal markets from 1970 through 1988. This presentation parallels that for beef shown in Figure 10.

Hog prices were lower in 1988, but at least some decline in prices are inevitable if aggregate production is up almost 9 percent. The own-price demand elasticity for products at the producer level is more "inelastic" than at the retail level, with estimates ranging around -.5. An elasticity coefficient of -.5 suggests each 1 percent increase in quantity will bring a 2 percent decline in price. The 7-market price series for barrows and gilts averaged $51.69 per hundred in 1987. If the level of demand had been the same in 1988 as in 1987, hog prices would have declined by 18 percent, down to $42.38.

The 1988 prices were above $42.38 in spite of an 8 percent increase in the farm-retail price spread. If the spread had remained at the 105.7 cent level of 1987, live hog prices would have been around $47.52

Figure 17. Retail Pork Prices, Farm-Retail Price Spreads, and 7-Market Hog Prices, Omaha, 1970-88



versus the observed $44 price level. Increased demand for pork boosted producer-level hog prices in 1987 and again in 1988.

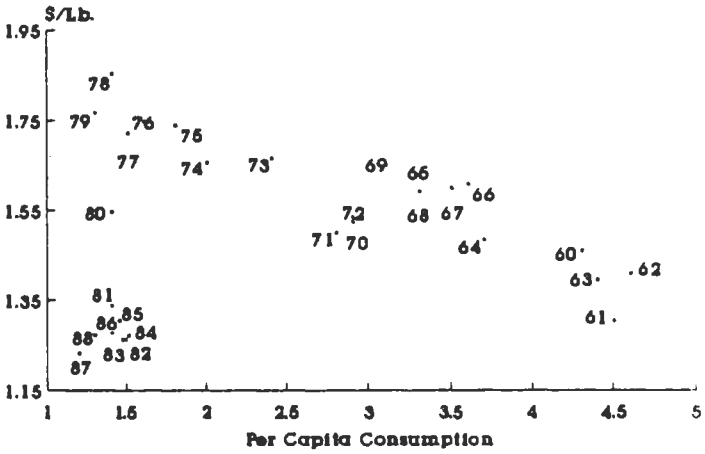
Periodic decreases in demand for pork during the 1980-86 period forced herd liquidation. Pressure from expanding price spreads and increased processor costs pushed hog prices below breakeven levels periodically during the period. A reversal in the overall trend and increases in demand in 1987 and in 1988 supported live hog prices and restored a base of viability to the hog sector. Continued improvement in demand for pork would encourage increases in production levels and restore the pork sector to the status of a "growth industry" and allow it to capture a larger market share.

Demand for Lamb

Analysis of demand for lamb is complicated by the absence of a retail price series from 1981 through 1988. Wholesale prices are available, but use of wholesale prices eliminates examining what has happened to the farm-retail price spread across the years that demand for the red meats experienced major problems.

Figure 18 records a scatter plot of deflated *wholesale* prices for lamb and per capita consumption for the 1960-88 period. In recent years, the per capita consumption levels have been around 1.5 pounds in retail weight equivalent, and the estimated consumption levels have been quite constant. With minimal variation in consumption levels and the availability of only wholesale prices, inferences from this scatter plot must be made with care.

Figure 18. Per Capita Consumption and Deflated Wholesale Prices for Lamb and Mutton (1982-84 = 100) 1960-88



The plot demonstrates the tendency toward decreased inflation-adjusted prices to move essentially a constant supply into consumption, especially during 1979-82. This is the same tendency observed in beef and pork during the late 1970s and early 1980s. There is some tendency toward better prices in the mid 1980s, but this could be from either improved demand and higher consumer prices or from a contraction of farm-retail price spreads as the processing sector has consolidated and moved to large and potentially efficient operations.

Figure 19 provides an alternative scatter plot showing the relationship between commercial production and deflated lamb prices. Using commercial production avoids the concerns over the sensitivity of the very small per capita consumption levels, and the lamb prices show the impact at the producer level of any problems on the demand side. During

the early 1980s, there is a pattern of lower prices and lower levels of production, but the 1985 price-quantity combination does suggest improvement compared to 1982, for example.

There is less research on the nature of the demand for lamb and little or no consensus as to the level of the demand elasticity parameter. Imports are a high percentage of total U.S. supply (around 10 percent) in recent years, and that complicates the examination of the relationship between price and commercial production.

To parallel earlier treatments of beef and pork, Figure 20 examines the year-to-year changes in lamb and mutton for 1987 to 1988. Total supply, including imports, of lamb and mutton increased from 372 million pounds in 1987 to 397 million in 1988, a 6.7 percent increase. Slaughter lamb prices decreased from $78.08 to $67.00 in nominal terms, from $68.49 to $58.34 in deflated terms. The $68.49 to $58.34 decline was a 14.8 percent decrease. If the demand elasticity for lambs at the farm level is around -.5, price would have dropped by 13.4 percent if the level of demand in 1988 was the same as in 1987 and the 1988 price would have been $59.31. Based on these data, it appears the demand for lamb declined in 1988 relative to 1987, but only slightly.

The earlier caution deserves repeating here. It is *retail prices* that consumers respond to, not slaughter lamb prices. If retail prices were up in 1988 relative to 1987 or, given the increase in total supply, were at or near 1987 levels, then any conclusions about weaker demand need to be modified.

Table 4 records retail lamb prices taken from private sources during 1987 and 1988 in nominal and deflated terms. Prices at retail were periodically higher during 1988 in nominal terms with the deflated prices essentially constant after quarter 1 of 1987. This limited evidence supports a conclusion of better performance on the demand side than the slaughter lamb prices had suggested. Implicitly, it appears that at least part of the downward pressure on lamb prices during 1988 came not from resistance by consumers, but from expanding farm-retail price spreads -- and we have no data on these spreads that are publicly available.

Figure 19. Commercial Lamb/Mutton Production and Deflated Lamb Prices (Choice, San Angelo) 1970-88

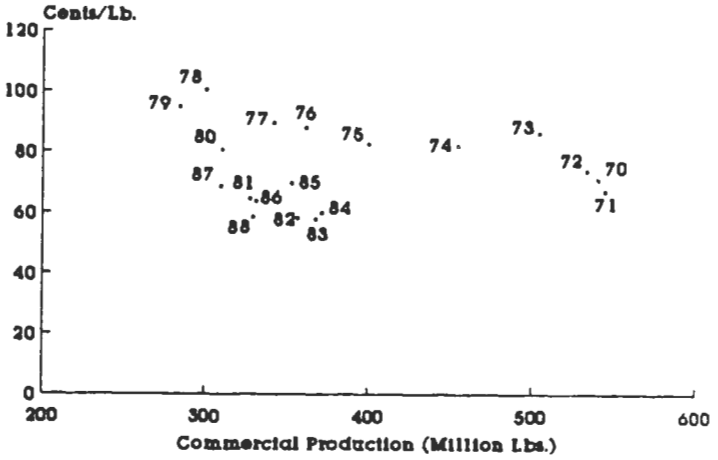


Figure 20. Demonstration of Shifts in Demand for Lamb/Mutton, 1987 and 1988

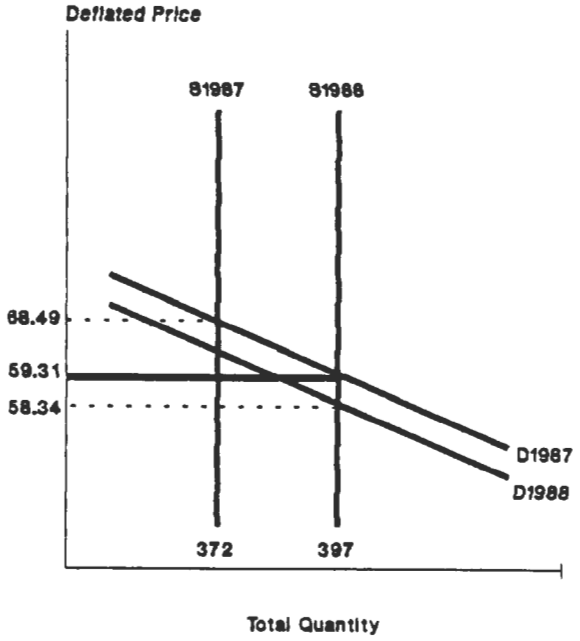


Table 4. Retail Lamb Prices by Quarters, 1987-88
Nominal and Deflated (1982-84=100)

Year (Quarter)	Nominal Price ($ per lb.)	Deflated Price ($ per lb.)
1987.1	$3.18	$2.85
.2	3.12	2.76
.3	3.16	2.76
.4	3.16	2.74
1988.1	3.19	2.75
.2	3.20	2.72
.3	3.16	2.65
.4	3.28	2.72

Examination of the limited data that are available suggests that demand for lamb experienced some of the same problems that characterized the other red meats during the 1980s. There are signs of recovery in recent years, however, especially in 1987 and 1988. If improvement in demand does develop and persist, the opportunities for the industry to expand production levels and compete for a larger market share will be enhanced.

Demand for Broilers

The focus of attention in this section will be on broilers. In the earlier developments, the production and consumption patterns for broilers, turkeys, and total poultry were shown. Production levels have expanded, especially in recent years, and related increases in per capita consumption have been recorded. Market and product development in broilers and turkeys have followed a similar pattern with an emphasis on further processing and product development for all segments of the consuming public. An emphasis on broilers will capture the important facets of what is happening to demand for poultry.

For broilers, the picture for the 1980s is significantly different from that for the red meats in two important respects. First, there is a tendency for year-to-year changes during the 1980s that indicate increased movement into consumption at higher deflated prices. Second, the longer term tendency that was carried into the 1980s was for increases in per capita supplies at downward trending deflated prices.

The second characteristic, the continued increases in per capita supplies, is counter to what was observed for the red meats. As inflation-adjusted beef prices moved lower in the 1980s, forced herd liquidation continued and per capita supplies were largely constant. In pork, per capita supplies tended to move lower from 1980 through 1986 as deflated prices fell under the weight of decreases in demand. Limited data suggest the same pattern was present in the sheep sector.

A capacity to expand total output and per capita supplies in the poultry sector could come from two sources. Cost-reducing technology and efficiencies associated with vertically coordinated activities apparently reduced per unit costs and retained resources in broiler production in spite of downward trending prices. There was new investment and new capacity rather than industry-wide contraction.

The success in terms of cost-reducing technology in poultry has been widely documented, and will not be discussed in detail here. The *observed* pattern in Figure 21 suggests that technology was important. It is a recorded fact that per capita supplies were expanding in the presence of deflated prices that were trending lower as late as the early 1980s.

In recent years, expanded production and increased market share have been aided by stabilizing demand. Both Figure 21 and Table 5 document year-to-year changes during the 1980s that suggest demand was increasing. The 1983 to 1984 and the 1985 to 1986 changes suggest increasing demand, and the 1987 to 1988 developments suggest the pattern of increased demand in alternate years is continuing.

Overall, the demand picture for broilers is significantly better than that for the red meats. Demand increases in the 1960s and well into the 1970s kept beef and pork in a "growth industry" mode. Then, some time in the late 1970s, the pattern was apparently reversed and the red meats were described as "mature" industries. The growth potential associated with increasing demand was gone, and the red meats have gone through a period of contraction and forced disinvestment.

For broilers, an argument could be made that the industry operated around a single long-run demand curve until about 1983. Year-to-year changes in the 1970s would occasionally record what then looked like a shift in demand. But in subsequent years, the price-quantity coordinates tended to come back and operate again around the long-run demand surface. The "law of demand" which states that consumers will tend to take more only at lower prices appeared

Figure 21. Per Capita Consumption and Deflated Retail Prices for Broilers (1982-84=100), 1960-88

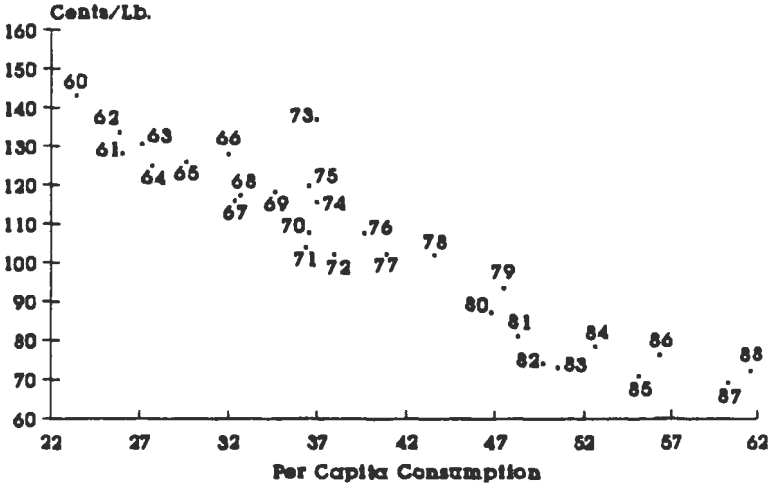


Table 5. Per Capita Consumption and Price of Broilers at Retail, Actual and Deflated (CPI, 1982-84=100), 1970-1988

Year	Per Capita Consumption (lbs. retail weight)	Retail Price (cents/lb.)	Deflated Retail Price (cents/lb.)
1970	36.5	41.7	107.5
71	36.3	42.0	103.7
72	37.9	42.7	102.2
73	36.9	60.8	136.9
74	36.9	57.0	115.6
75	36.5	64.3	119.5
76	39.6	61.1	107.4
77	40.8	61.9	102.1
78	43.5	66.5	102.0
79	47.4	67.7	93.3
80	46.7	71.9	87.3
81	48.2	73.7	81.1
82	49.6	71.6	74.2
83	50.4	72.8	73.1
84	52.6	81.4	78.6
85	55.1	76.3	71.0
86	56.3	83.5	76.2
87	60.2	78.5	69.1
88	61.5	85.4	72.2

to be in effect. It developed that the industry *could* expand output and *could* reduce costs enough to keep the resources in place, however. In the late 1980s, it appears the broiler industry is in the middle of a growth phase not unlike that which was observed for beef in the 1960s and 1970s.

Figure 22 continues the type of development presented earlier for beef, pork, and lamb. Focusing on the 1986, 1987, and 1988 years, the pattern of demand increases in alternate years that first appeared in 1983 is repeated. The 1986 to 1987 change suggests operation on the same level of demand. If a demand elasticity around -.67 is applied to the price and quantity changes recorded in Table 5, there is reason to argue that the two years were on the same level of demand, on the same demand curve. Quantity increased by 6.9 percent, and the deflated price decreased by 9.3 percent. Those changes would be roughly consistent with a demand elasticity parameter around -.67.

The 1988 price-quantity coordinate cannot be explained via movements along the 1987 demand curve, however. Both quantity and price increased, a sure sign of an increase in demand. This is the same response that appeared in 1986, and it argues well for the near-term future of the broiler sector.

Recent developments in poultry suggest demand has increased periodically during the 1980s. In combination with cost-reducing technology and the investment of new resources, the increases in demand have prompted significant expansion in output. As production of poultry expands relative to the red meats, the market share captured by poultry will continue to increase unless expansion in the red meats is stimulated by a changing demand situation and long-term outlook.

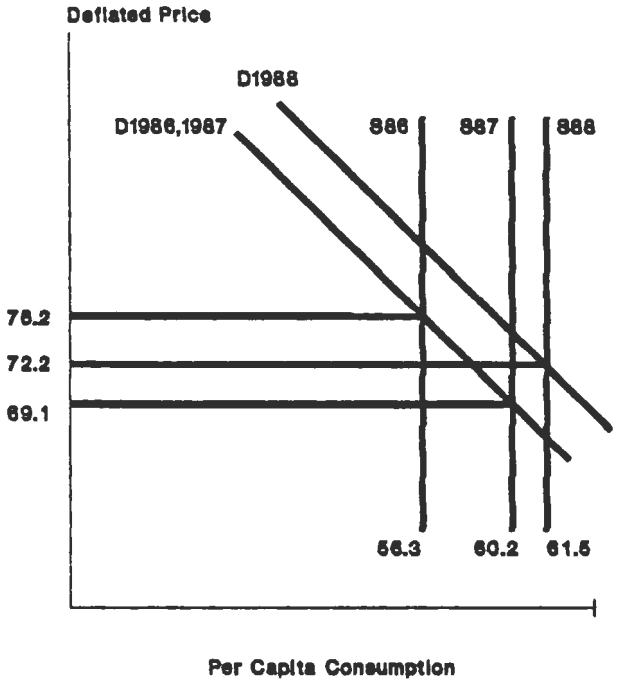
Measures of Demand

It is important that decision makers at the individual level and industry leaders understand what demand is and is not. In earlier discussions, several references have been made to the problems that emerge when efforts to identify the level of demand or shifts in demand employ only consumption or only price. Demand is *price and quantity,* and the distinction between demand and quantity consumed, for example, is extremely important.

One widely used measure of the level of demand is percent of income consumers spend on a particular commodity. On the surface, this would appear to be a legitimate measure of demand and an effective way to identify changes in demand since both price and quantity are involved in the calculation. If the percent of income spent on beef declines, for example, is this not proof that the demand for beef is declining?

The answer is an emphatic "no" -- the measure "percent income spent on beef" is not a conceptually sound measure of demand, and the statistic has been and is a misleading indicator. In this section, the

Figure 22. Demonstration of Shifts in Demand for Broilers, 1986-88



problems with this particular measure will be explored. Given the understandable desire for a simple "measure" of demand, a modification of the measure designed to make it more nearly a sound and legitimate measure will be presented.

Percent of Income as a Measure of Demand

Conceptually, the statistic is calculated as follows:

$$\frac{\textit{Expenditures on Commodity A}}{\textit{Consumers Disposable Income}}.$$

Since expenditures are price times quantity consumed, it does appear that the essential price-quantity relationship is being captured. The difficulty is that the numerator of the ratio, expenditures, is distorted by the implications of changes in quantity. When per capita supplies and therefore per capita consumption is declining, the expenditures measure will be biased upward. Conversely, when per capita consumption is increasing, the expenditure measure is biased downward.

The difficulty emerges from the "inelastic" nature of demand for meat products such as beef. Earlier, the concept of elasticity was discussed as a property of demand. Current research suggests the demand for beef, for example, has an own-price elasticity of -.67. To review, that suggests a 2 percent change in quantity would result in a 3 percent change in price in the opposite direction *if the level of demand is constant.*

Given this property of beef demand, expenditures on beef will increase if per capita supplies are being reduced *even if the level of demand is constant.* Conversely, for a constant level of demand, increasing per capita supplies of a product facing an inelastic demand (the coefficient is less than 1.0 in absolute value) will mean expenditures will be reduced solely due to the quantity change. In application, therefore, the expenditure measure will be inflated during periods of declining per capita supplies and the statistic percent of income spent on beef will be boosted accordingly. If this is the measure being monitored as an indicator of the level of demand, the statistic could be constant or even increasing *due solely to the reduced quantities* while, behind the scene, the level of demand is declining.

Figure 23 demonstrates the problems. In moving from point A to point B on the demand curve, which means the *level* of demand does not change, expenditures will increase. Each percentage change in quantity brings a larger (1.5 percent) increase in price, and expenditures increase. So long as the percentage increase in expenditures exceeds the percentage increases in income, the percent of income spent on beef will increase. But this clearly does not indicate an increase in demand.

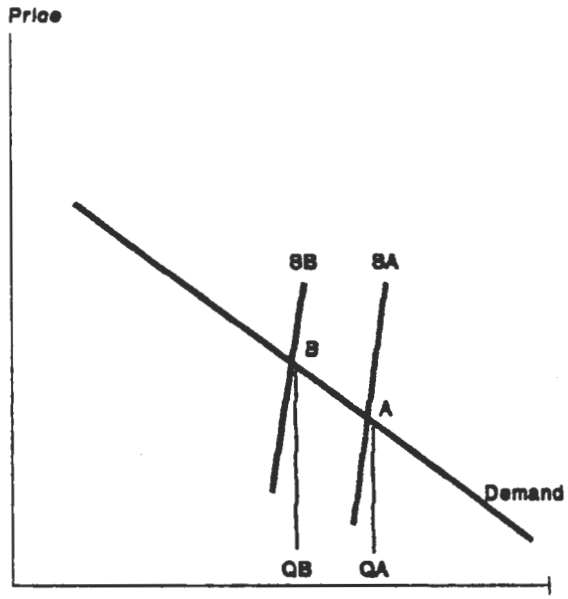
The problems with the statistic are apparent when the price, quantity, and percent of income spent on beef measure are examined during the 1970s and 1980s. Table 6 records the data.

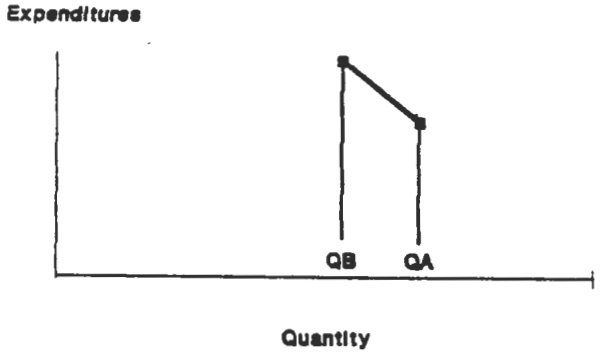
During the late 1970s, per capita consumption was declining relative to the peak level in 1976. The "percent income on beef" measure was relatively constant, and observers were inclined to infer the demand was relatively stable. But the decreases in per capita consumption were inflating the measure, given the inelastic nature of demand for beef. It was not until 1980 when per capita consumption started to stabilize that the percent income measure showed significant declines.

During the late 1970s, therefore, the influence of the declining per capita supply levels distorted the measure and gave rise to false impressions that all was well with demand for beef. Clearly, the opposite case is also present. If per capita supplies are *increasing,* then the percent income measure would be forced lower, and would tend to overstate any problems on the demand side.

To correct for the problem and generate a simple but more nearly correct measure of the level of demand, the impact of changes in quantity need to be eliminated. Procedurally, the *expenditures* data need

Figure 23. Relationship Between Shifts in Quantity and Expenditures When Demand is Inelastic





to be calculated as follows as year-to-year changes are monitored:

$$CorPr_{t+1} = ObsPr_{t+1} - \Delta Prq$$

where

$CorPr_{t+1}$ = corrected price in year t + 1,
$ObsPr_{t+1}$ = observed price in year t + 1, and
ΔPrq = price change from year t to year t + 1 due solely to change in quantity.

The ΔPRq measure comes directly from the elasticity framework as follows:

$$Elasticity = \frac{Percent\ Change\ in\ Quantity}{Percent\ Change\ in\ Quantity}$$

$$-.67 = \frac{Percent\ Change\ in\ Quantity}{X}$$

and "X" will be the percentage change in price associated with an observed change in quantity if demand is constant. Solving for X will give the ΔPrq needed in the calculation of a corrected price series. For reductions in per capita supply, X or the ΔPRQ measure will be positive since the entire ratio is equal -.67. The "corrected price" will thus be lower than the observed price and when "corrected expenditures" are calculated, the upward bias due strictly to the reduced quantity will be removed. During periods of increasing per capita consumption, of course, then ΔPrq will be negative and the corrected price will be *above* the observed price. Corrected expenditures would then be boosted relative to the calculation using uncorrected prices.

Table 6 demonstrates the impact, showing nominal retail prices and a "corrected" column of prices. Both the widely used and a corrected percent income on beef data are shown. During the late 1970s, the corrected percent of income spent on beef started to decline, and could have been a warning indicator to the industry. In 1977, the nominal price was below the price that should have occurred given the year-to-year changes in supply. That same pattern was repeated in 1981 and in 1985-87, suggesting

Table 6. Beef Prices and Percent of Income Spent on Beef Corrected for Year-to-Year Changes in Per Capita Supplies, 1970-88

Year	Per Capita Consumption (lbs. retail)	Nominal Price ($ lb.)	Corrected Price ($ lb.)	Percent Income/Beef Nominal (Percent)	Corrected (Percent)
1970	84.4	1.02	--	2.55	--
71	83.7	1.08	1.03	2.56	2.40
72	85.5	1.19	1.05	2.66	2.35
73	80.5	1.42	1.29	2.69	2.44
74	85.4	1.46	1.29	2.72	2.40
75	88.0	1.55	1.39	2.71	2.43
76	94.2	1.48	1.39	2.58	2.42
77	91.4	1.48	1.55	2.30	2.41
78	87.2	1.82	1.58	2.42	2.11
79	78.0	2.26	2.11	2.44	2.27
80	76.4	2.38	2.33	2.16	2.11
81	77.1	2.39	2.41	1.99	2.01
82	76.8	2.43	2.40	1.92	1.90
83	78.2	2.38	2.36	1.80	1.78
84	78.1	2.40	2.38	1.66	1.65
85	78.8	2.33	2.37	1.54	1.57
86	78.4	2.31	2.35	1.45	1.48
87	73.4	2.43	2.53	1.35	1.41
88	72.7	2.59	2.46	1.31	1.24

shifts in demand were occurring. The decline in the corrected percent income series from 1977 to 1978 suggests problems first emerged in 1977.

In moving toward a more correct measure of demand, the expenditure calculation needs to be:

$$CorExp_t = Q_t \, x \, CorPr_t$$

The percent of income spent on beef is then:

$$Cor\ Percent\ Income_t = \frac{CorExp_t}{Income_t}$$

To use the "percent income spent on beef" or any meat product as a measure of changes in demand, the price in any year t must be corrected for the influence of changes in quantity from year t-1 to year t. This process of adjustment eliminates the distortion that came from the year-to-year price changes that are due solely to a change in year-to-year supplies or consumption.

Overall Observation

With the proper corrections, the "percent income" statistic can be a useful indicator of what is happening to demand. With the corrected measure, however, a few cautions are in order when the measure is being used.

The "corrected price" is calculated using a measure of demand elasticity. If the true coefficient is not -.67 as used here to illustrate, the corrections will be incorrect. Estimates of the demand elasticity parameter will be developed in later sections when the demand for the meats is modeled.

Year-to-year changes in the corrected statistic are more reliable indicators that demand is shifting, but those changes do not indicate *why* the shifts are occurring. If the corrected statistic is decreasing, the conclusion is that demand could be declining. But those declines are documenting a lack of willingness to continue spending a constant proportion of income on beef or some other product. That lack of willingness could come from a change in lifestyles and preference patterns, changes in prices of competing products (the cross elasticity phenomenon), or from changes in the relationship between changes in income and quantity that will be taken at constant prices (the income elasticity phenomenon).

It is important to know that changes are occurring, however. Evidence that demand is shifting encourages early concern about "why" and encourages efforts in research on consumer behavior, in product development, and other possible responses to the problems or to the opportunities that appear to be present.

Basics of Demand Analysis

The primary objective of demand analysis is to measure the impact of selected economic forces on quantity consumed or on price. In modeling the important relationships, the first step is to conceptualize the direction of the causal flows between a set of *independent* or *explanatory* variables and the variable selected as the *dependent* variable.

Initial conceptualization of the relationships involves the issue of *identification.* If quantity is the dependent variable, for example, is the initial specification representative of a demand curve or a supply curve? A mathematical fit between economic variables is just that, and the "fit" does not tell the analyst what they have. If, given the data employed, it is conceptually impossible to determine whether changes in price cause changes in quantity or changes in quantity cause changes in price, there is simultaneity inherent to the economic relationships. There are causal flows in both directions. A single-equation modeling approach is not appropriate, and a set of equations will be required to properly capture the economic relationships. Figure 24 shows a price-quantity path over time that involves shifting demand *and* shifting supply curves. The price-quantity causal flows could be running in both directions, and a set of equations to capture both the supply and demand shifts would be required.

If the price-quantity data are yearly data, there will often be simultaneity involved, especially in the livestock sector. The number of cattle on feed in quarter 1, for example, will influence the price of cattle in quarters 2 and 3. Price levels in quarters 2 and 3, in turn, can influence the number of cattle on feed in quarters 3 and 4. Thus, within the year, the quantity of cattle on feed *and* the price of fed cattle can be adjusted within the year. The result can be problems if a single-equation modeling approach is desired where either quantity of beef or price of beef has to be selected as the dependent variable.

Much the same thing can occur within the year in pork and in poultry. Changes in price of hogs can influence producers' decisions on gilt retention or liquidation, and those actions can influence the quantity of slaughter hogs coming to market within the year. Since the producers' decisions on gilt retention influence the supply of slaughter hogs, price of slaughter hogs can be influenced within the year. In poultry, the egg set and the chick hatch can be adjusted within the year in response to changes in

Figure 24. The Identification Issue Demonstrated via Shifting Demand and Supply Curves

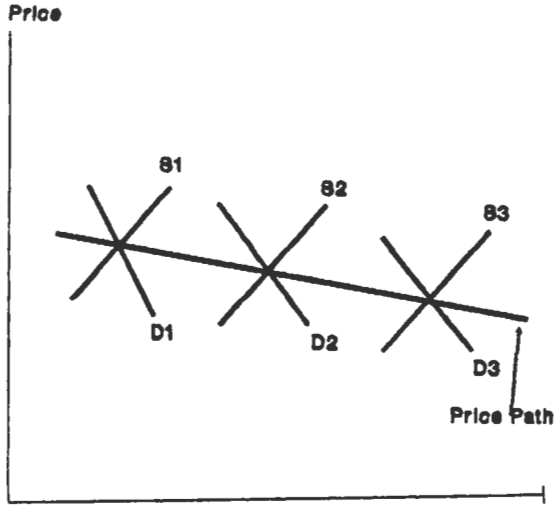
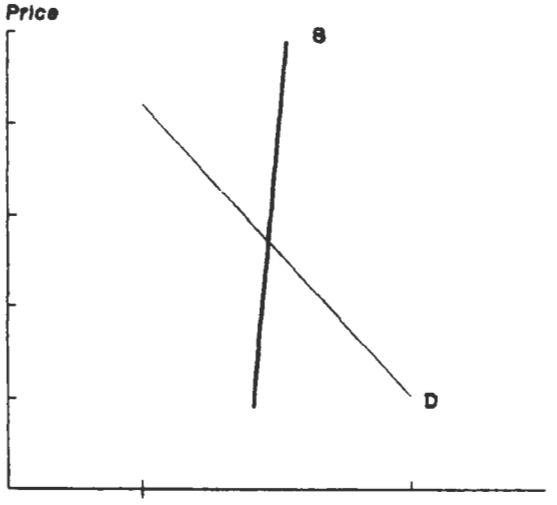


Figure 25. Demonstration of a Highly Inelastic Supply Curve for a Given Time Period



the prices or price expectations for broilers. An increased or decreased hatch influences broiler prices within the year. Thus, in hogs and in the poultry sector, the issue of simultaneity arises.

The simplicity of single-equation models is appealing. If the issue of direction of causal influence can be resolved, single-equation models are generally preferred by users. This is especially true for private sector applications where training in economics and/or econometrics may be limited.

In the analysis section to follow, the initial models employed are single-equation models with price as the dependent variable. Quarterly data are employed to enable the analysis to measure the seasonal patterns. The use of quarterly data also help to resolve the issue of simultaneity. For a particular quarter, the supply of beef, pork, poultry, or lamb has been largely pre-determined by decisions made prior to the quarter. Decisions on the breeding herd in hogs, the number of cattle or lambs placed on feed, the number of chicks placed, etc. in previous quarters essentially determine the quantity of beef, pork, lamb, and poultry during a particular quarter. It is *price* that will adjust to the largely autonomous changes in quantity. Conceptually, the situation is pictured in Figure 25. The supply curve for the quarter approximates a vertical line or completely inelastic supply curve. With little or no capacity for quantity to be adjusted within the quarter, price will be determined by the level of demand for the quarter. It is *price* not quantity, it could be argued, that is the conceptually correct choice for the dependent variable.

One problem with the price-dependent approach to modeling is the complications it offers in calculating key elasticity parameters. To shed light on those problems and provide comparisons, the demand relationships are also modeled on a quantity-dependent basis. To many analysts this is *the* correct approach since, technically, demand is the schedule of quantities consumers will take at alternative prices. In other words, it is *quantity taken by consumers* that is dependent upon prices and other economic measures. The parallel analysis involving both price-dependent and quantity-dependent specifications will be completed for all the meats where data availability allows the parallel approach.

Scope of Analysis

Quarterly data across the 1960-87 time period will be employed in the analyses. The objectives are:

1. To explain the variability in quarterly prices or in quarterly per capita consumption;
2. To estimate the price-quantity relationships and estimate important parameters such as price flexibility, own-price demand elasticity, cross price flexibility, and income flexibility;
3. To identify shifts in demand that cannot be explained by changes in income and/or prices of related (especially substitute) products; and
4. To identify and document changes in important price and income parameters that will influence consumer buying patterns in the future.

The objectives are the same for the alternative specifications with quantity as the dependent variable. Comparisons of the alternative estimates of the key elasticity parameters will be presented and discussed.

The analytical results will be used to explain what has occurred in the red meats and poultry across the

1960-87 time period. Earlier, descriptive evidence was presented that suggests, for example, that demand for beef declined significantly during the 1979-86 time period. An overall purpose of this analysis is to empirically test for the presence of a significant change in demand for beef starting in the late 1970s. Apparent changes in demand for pork, lamb, and broilers will be examined in a similar manner. Models will be estimated for the 1960-87 period and for the 1975-87 subperiod. Data for 1988 will be used to provide "out of sample" tests of the models.

Demand for Beef: The Conceptual Framework

The general specification of the single-equation, price-dependent model of the demand for beef is:

$$P_t = a + b_1Q_t + b_2I_t + b_3Q_{pt} + b_4Q_{ct} + b_5YDUM_t + b_6SDUM_t + b_7SLDUM_t + e_t$$

Variables in this general model formulation are defined as:

P_t = price of beef in quarter t (cents/lb.);

Q_t = per capita consumption of beef in quarter t (lbs. retail weight);

I_t = per capita disposable income in quarter t ($);

Q_{pt} = per capita consumption of pork in quarter t (lbs. retail weight);

Q_{ct} = per capita consumption of broiler chickens in quarter t (lbs. retail weight);

$YDUM_t$ = yearly 0-1 dummy variables to identify yearly shifts in beef prices not accounted for by other economic forces in the model (0, 1);

$SDUM_t$ = quarterly 0-1 dummy variables to identify seasonal patterns in beef prices not accounted for by other forces in the model (0, 1);

$SLDUM_t$ = a slope dummy to be employed in estimating any hypothesized change in the relationship between a continuous variable, such as consumer income, and the dependent variable during an apparent period of transition such as 1979-1986; and

e_t = an error term that captures all changes in quarterly beef prices not explained by the model.

The model specification is based on economic theory and explanatory variables are included only if there are *a priori* economic reasons to expect a significant relationship between each explanatory variable and the price of beef. For each of the explanatory variables, the economic support for inclusion and the expected sign on the beta coefficient are discussed below. This discussion will not be repeated in detail for each of the meats. Reasoning will be similar for pork, lamb, and chicken.

The Q_t variable captures the expected inverse relationship between price and quantity. For a given *level* of demand, the "law of demand" indicates consumers will take more only at a lower price. The sign on b_1 is therefore expected to be *negative*.

The coefficient on the I_t variable will estimate the relationship between income and the price of beef. Theory suggests that for a "normal" good, the demand for a product will increase as incomes increase. Since the estimate of b_2 will quantify the relationship between income and price of beef with quantity of beef and all other explanatory variables held constant, the sign on b_2 should be *positive*.

The estimates of b_3 and b_4 will measure the relationship between changes in per capita consumption of pork and chicken respectively and the price of beef. This is the *cross over* phenomenon, and it is changes in the price-quantity levels for substitute goods that can shift the demand curve for a product such as beef. When the per capita supplies of pork or chicken increase, their price would be expected to decline. Lower prices for pork and chicken will decrease the demand for beef, higher prices would increase the demand. Therefore, the signs on b_3 and b_4 should be *negative*.

In estimating parameters for yearly dummies such as b_5, the expected sign will depend on what impact the yearly dummy is hypothesized to be capturing. There could be several yearly dummies in the final specification. One might be used to capture the impact of the price ceilings in 1973, for example. Since beef prices increased rapidly in the early 1970s and prompted the imposition of price ceilings coming into 1973, the sign on a 0-1 dummy variable would be expected to be *positive*.

For other years, the expected sign on yearly dummies depends on the circumstances. In the earlier graphical exposition, the scatter plot for beef suggested demand decreased from 1979 through 1986, with possible declines in 1987 and 1988 as well. The sign on the 0-1 dummy for a year in the late 1970s would be expected to be *negative*. The variable is picking up the shift of the price-quantity relationship that is not explained by the economic forces in the model.

The sign on the estimated beta coefficient such as b_6 for the seasonal dummies will depend on the quarter being considered. Since quarter 1 is the "base" quarter, a priori expectations for beef might be for a positive sign on the coefficient for quarters 2 and 3, and a negative sign for quarter 4. Quarter-to-quarter changes in cattle on feed preclude any certain set of a priori expectations, however.

The slope dummies are employed when there is reason to hypothesize that the nature of the relationship has changed. For example, consumers' reactions during the 1980s gives reason to hypothesize that the relationship between income and beef prices might have changed. During a period in which consumers were concerned about health-related issues and product convenience, the propensity to spend increases in income on beef apparently changed. The sign on the slope dummy that is tied to income would therefore be expected to be *negative.*

Modeling Beef Demand

Based on the descriptive presentations and the conceptual framework developed earlier, beef demand was modeled for the 1960-1987 period using quarterly data. The primary objectives of the analysis were:

1. To determine whether there is statistical evidence of a structural change or shift in preferences for beef during the 1975-1987 period, and

2. To estimate key parameters of the relationship between price and/or quantity of beef and income plus price-quantity patterns in the competing meats.

The variables employed in the various model specifications are defined below. All price and income variables were deflated using the Consumer Price Index (CPI, 1982-84 = 100).

- BEEFDEF = quarterly average retail Choice beef price (cents per lb.)
- PORKDEF = quarterly average retail pork price (cents per lb.)
- BROIDEF = quarterly average retail broiler price (cents per lb.)
- DEFINC = quarterly average per capita disposable income (dollars)
- BEEFCON = quarterly per capita consumption of beef, retail weights (pounds)
- PORKCON = quarterly per capita consumption of pork, retail weights (pounds)
- BROICON = quarterly per capita consumption of broilers, retail weights (pounds)
- DUM73 = 0-1 dummy variable to allow for intercept shifts during the price ceiling year of 1973 (1 for all quarters, 1973, 0 otherwise)
- DUM75 -- DUM87 = 0-1 dummy variables to allow for intercept shifts during 1975-1987 (1 for all quarters for each respective year, 0 otherwise)
- QDUM2 -- QDUM4 = 0-1 dummy variables to account for seasonal impacts in quarters 2, 3, and 4 (1 for a respective quarter across all years, 0 otherwise)
- SLOPINC75 -- SLOPINC87 = interactive slope dummy to account for changes in the relationship between price/quantity of beef and income during the 1975-1987 period (value of DEFINC for all quarters of each respective year, 0 otherwise)
- TIME = a time trend variable taking the values 1 through 112 for the quarterly observations from 1960.1 through 1987.4.

The initial model formulation for the 1960-87 period employed only the traditional economic variables and the seasonal dummies. Table 7 records overall statistics and the estimated beta coefficients.

The model explains less than 50 percent of the variability in deflated beef prices, and there are apparent problems with the model specification. The sign on the estimated beta for PORKCON is conceptually incorrect, but the variable is marginally significant. The Durbin-Watson statistic indicates the presence of autocorrelation, suggesting the error terms or residuals from the fitted model will be correlated. The presence of autocorrelation raises questions about the effectiveness of the efforts to estimate the beta coefficients and correctly "fit" the model.

Figure 26 demonstrates the severity of the specification problems. Residuals from the model in Table 7 are plotted starting with quarter 1 of 1975. A string of positive residuals in the 1978-83 period indicates the model was consistently underestimating deflated beef prices. Then, in late 1983, a long string of negative residuals indicates the model was overestimating price. Clearly, the traditional economic explanatory variables were not adequate to explain price developments in beef in the late 1970s and 1980s.

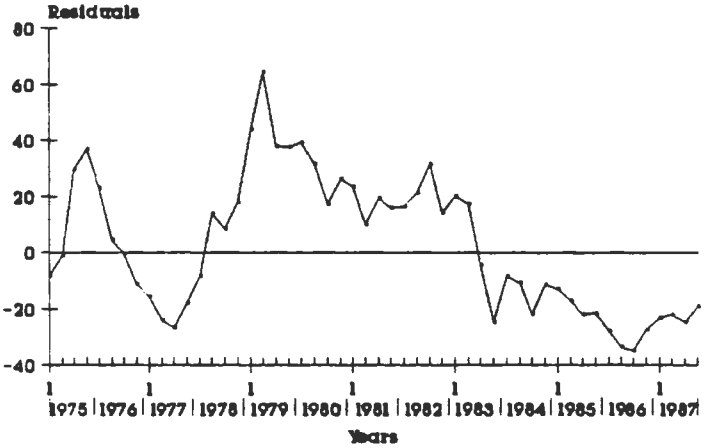
The pattern in the residuals, especially during the 1980's, appears to be consistent with the earlier graphical expositions. Both developments suggest the demand surface for beef shifted starting some time in the late 1970s. Alternative model formu-

Table 7. Summary Statistics and Estimated Beta Coefficients for a Preliminary Price-Dependent Model, Beef, 1960-87

Dependent Variable	BEEFDEF
Standard Error of Regression	12.297
R-squared	.449
Adjusted R-squared	.412
F Statistic (7, 104)	12.096
Probability Value for F	.000
Mean Squared Error	38727.26
Durbin-Watson Statistic	.353

Variable	Coefficient	T-Ratio	Prob > T
INTERCEPT	200.568	5.678	.000
BEEFCON	-7.040	-3.957	.000
PORKCON	2.453	1.487	.136
BROICON	-23.560	-8.195	.000
DEFINC	.041	6.862	.000
QDUM2	24.260	4.113	.000
QDUM3	27.624	4.358	.000
QDUM4	-4.292	-.806	.427

Figure 26. Plot of Residuals for the Preliminary Price Dependent Model, Beef, 1975-87



lations were tried to correct the specification problems.

A single shift dummy (0-1 dummy variable) was tried starting in various years in the late 1970s and early 1980s. The R-square measures improved, but the problems with the PORKCON variable persisted and autocorrelation was still a problem. A slope dummy was incorporated for the income variable, but it proved to be statistically insignificant and the modeling effort was not improved.

Yearly shift dummies were incorporated, and the improvement in model performance was dramatic. The final model employed is presented in Table 8. Shift dummies for 1977-87 were generally highly significant. Using a number of shift dummies would be expected to increase the R-square measures, but important analytical problems were eliminated. The Durbin-Watson statistic moved to the indeterminate range, and the problems of autocorrelation disappeared. Figure 27 provides a plot of the residuals across the 1975-87 period. There are no systematic patterns in the residual plot.

The BROICON explanatory variable has the correct sign, but is not statistically significant. It was kept in the model based on economic theory.

The seasonal dummy variables were retained on theoretical grounds and based on evidence of a seasonal pattern in the residuals in intermediary model runs that did not allow for a seasonal pattern. The 1979 shift dummy, DUM79, was retained to keep the continuity in the pattern of yearly shift dummies.

Examination of the correlation and covariance matrices raised the possibility that the BROICON variable was picking up a time-trend pattern in the

Table 8. Summary Statistics and Estimated Beta Coefficients for the Final Price-Dependent Model, Beef, 1960-87

Dependent Variable	BEEFDEF
Standard Error of Regression	8.371
R-squared	.907
Adjusted R-squared	.889
F Statistic (7, 104)	50.533
Probability Value for F	.000
Mean Squared Error	6517.11
Durbin-Watson Statistic	1.488

Variable	Coefficient	T-Ratio	Prob > T
INTERCEPT	331.003	18.237	.000
BEEFCON	-12.615	-10.403	.000
PORKCON	-3.264	-4.002	.000
BROICON	-1.150	-.416	.678
DEFINC	.028	9.463	.000
QDUM2	-2.039	-.566	.573
QDUM3	4.064	1.200	.233
QDUM4	-1.627	-.698	.487
DUM77	-31.895	-6.833	.000
DUM78	-20.590	-3.680	.000
DUM79	-5.719	-.659	.512
DUM80	-20.255	-2.275	.025
DUM81	-45.281	-4.696	.000
DUM82	-55.510	-5.620	.000
DUM83	-72.756	-6.943	.000
DUM84	-94.267	-8.350	.000
DUM85	-109.908	-8.845	.000
DUM86	-130.448	-10.024	.000
DUM87	-147.145	-9.109	.000

dependent variable, BEEFDEF. A linear time trend variable was included, and the model was re-estimated. A positive and significant time trend in BEEFDEF was present, but the coefficient on the BROICON was negative, did not change significantly in magnitude, and the t-ratio was still less than 1.0 in absolute value. All the yearly shift dummies except DUM79 were still statistically significant, and the estimated beta coefficients were all still negative and were larger in absolute value. None of the economic explanatory variables were influenced except the income variable, DEFINC. The estimated beta coefficient for the income variable was smaller with the time-trend variable in the model.

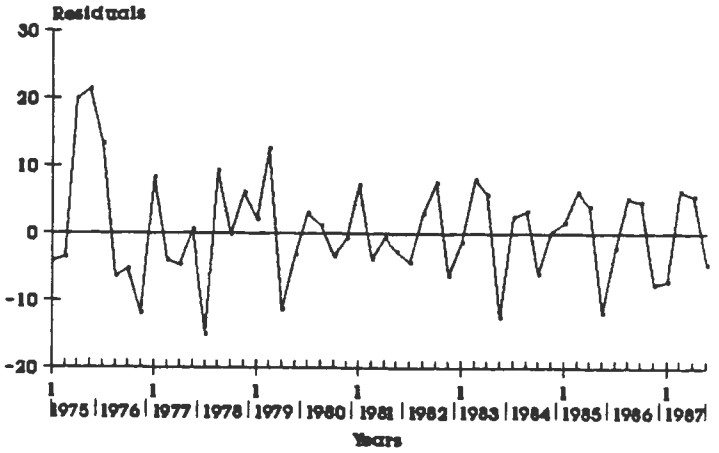
The time variable was not included in the final specification in Table 8. The income variable was highly correlated with time. Including both of the correlated variables would bring statistical problems of multicollinearity into the modeling effort. Time should always be employed as a last resort since it does nothing to explain the economic dimensions of beef demand.

Relevant and more specific observations about this estimation would include:

1. The coefficient on DEFINC, deflated personal income, is positive and highly significant. This is consistent with *a priori* expectations since beef is generally considered a "normal" good. Beef prices would be expected to increase with increases in income, other factors constant.

2. The PORKCON variable is negatively related to beef prices and, unlike the BROICON variable, is apparently a significant substitute for

Figure 27. Plot of Residuals for the Final Price Dependent Model, Beef, 1975-87



beef. As per capita supplies of pork and therefore per capita consumption increase, pork prices would be expected to decline. Lower pork prices will decrease the demand for beef.

3. The yearly shift dummies, starting with DUM77, are negatively related to beef prices and all but DUM79 are highly significant. Starting with 1977, the estimated beta coefficients increase steadily in absolute value to a level of -147.145 for the DUM87 variable. The inference is that demand for beef started to decrease in 1977, recovered slightly in the 1978-80 period, and then continued to decrease through 1987 in a manner that is not explained fully by the economic variables in the model.

In terms of estimated parameters, the -12.615 coefficient yields a price flexibility of -.960 at the mean levels of BEEFDEF and BEEFCON. A one percent change in quantity of beef consumed is associated with a .960 percent change in price in the opposite direction. The inverse of the price flexibility parameter yields an estimate of demand elasticity of -1.042. An estimate of -1.042 is larger in absolute value than most estimates of demand elasticity, but there are conceptual difficulties in this "inverse" approach to estimating demand elasticity. The -1.042 level is best interpreted as the lower bound on the demand elasticity coefficient, and should be used only with this constraint in mind. The quantity-dependent model to be developed later will help to identify the differences in the two approaches to estimation of demand elasticity.

At the mean levels of BEEFDEF and DEFINC, the income coefficient of .0282 generates an income flexibility of 1.019. A 1.0 percent increase in income will be associated with a 1.019 percent increase in beef prices, other things equal. Across the entire data set, there is strong and positive relationship between changes in income and changes in deflated beef prices.

The estimated beta coefficient for PORKCON, -3.264, generates a cross price flexibility parameter estimate of -.188 at the mean levels of BEEFDEF and PORKCON. A one percent increase in per capita pork consumption would be expected to bring a .188 percent decrease in beef price.

The estimated beta coefficient for BROICON was -1.150, reflecting the theoretically expected sign. At the mean levels of BROICON and BEEFDEF, the cross price flexibility would be -.044. This result suggests that broilers were a relatively weak substitute for beef compared to pork. Given the lack of significance of the BROICON variable, this parameter estimate should be used with caution.

Every effort was made to formulate a model that would be acceptable without the use of the yearly shift dummies. Given the earlier hypothesis of demand problems starting in the late 1970s, it was important to thoroughly investigate model formulations using only the traditional "economic" explanatory variables. The slope dummy for income was analyzed, and all reasonable combinations of the economic variables were tried. But the results were the same. Overall statistical measures were poor, and the Durbin-Watson statistic indicated the presence of autocorrelation. Analysis of the residuals for all formulations that did not include the shift dummies revealed a systematic pattern of large (negative) residuals starting in the early 1980s.

It is important to note that use of models including the yearly shift dummies indicate *demand for beef has shifted,* but the analysis is *not telling us why* the shifts have occurred. And attributing it all to a preference shift is too simplistic. It could be due to the redistribution of incomes that occurred in the 1980s. The demand for convenience by consumers as lifestyles changed and more households with multiple wage earners are probably important factors. These influences could be incorporated in "preference change", of course.

Part of the modeling difficulties could be due to the perpetual problem of data applicability and availability. The per capita consumption data are net "disappearance" data, and are not that precise. The dependent variable, BEEFDEF, represents the price of Choice beef in the retail supermarkets and does not reflect the growing presence of the away-from-home consumption. But the documented shifts are so dramatic, it is impossible to dismiss the results as a product of data problems.

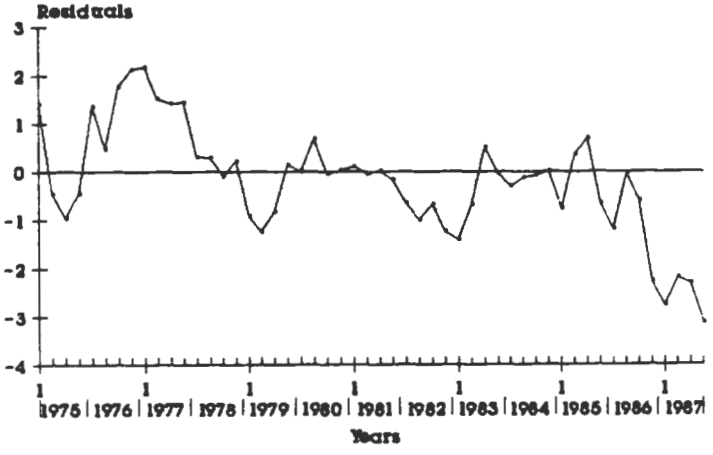
The price-dependent specification suggests demand problems for beef emerged starting in

1977. A significant decrease in price occured during 1977 that was not explained by the traditional economic factors of income and quantities of competing meats. The decreases continued through 1987.

Table 9 records the statistics and estimates of beta coefficients for a preliminary quantity-dependent model for beef that includes only the traditional economic variables and the seasonal dummy variables. The problems that emerged in the price-dependent modeling effort are present again. Autocorrelation is clearly present given the .325 value for the Durbin-Watson statistic, and the R-square levels suggest only 54 percent of the variability in the dependent series, BEEFCON, is being explained. Conceptually, the BROIDEF variable has the wrong sign.

Figure 28 provides a plot of the model residuals from quarter 1 of 1975 through 1987. Twenty-one of the last 25 observations are negative, with the absolute magnitude of the residuals for 1986 and 1987 starting to increase significantly. The -3.119 level for quarter 4 of 1987 was the largest residual in absolute terms across the entire 1960-1987 time period. It appears that the traditional economic variables were not adequately explaining the variation in per capita beef consumption during the late 1970s and 1980s.

Figure 28. Plot of Residuals for a Preliminary Quantity Dependent Model, Beef, 1975-87

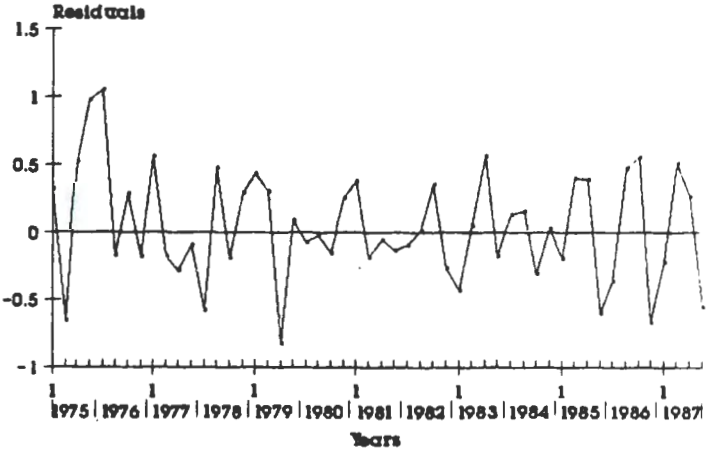


Alternative specifications were employed. A single shift dummy was incorporated starting with various years in the late 1970s and early 1980s, but the problems of autocorrelation persisted. An income slope dummy was incorporated to test the possibility that the response to income changes was different late in the analysis period, but it was insignificant and added little to the effectiveness of the modeling effort.

Having attempted without success to model the BEEFCON variable effectively without going to yearly shift dummies, shift dummy variables for the late 1970s and 1980s were incorporated. Table 10 provides the summary statistics and related measures for the final model that was selected.

Figure 29 provides a plot of the residuals for the final model for the 1975-87 period. As suggested by the Durbin-Watson statistic, the problems of autocorrelation are no longer present. There is no systematic patterns in the residual plot.

Figure 29. Plot of Residuals for the Final Quantity Dependent Model, Beef, 1975-87



There *are* apparent problems, and one in particular could not be resolved. The negative sign on the BROIDEF variable is inconsistent with theoretical expectations *if* we assume that poultry is a substitute for beef. The BROIDEF variable was highly correlated with the PORKDEF variable, suggesting problems of multicollinearity in the model specification. If the BROIDEF variable was deleted, however, it had no significance on the estimated beta coefficient for PORKDEF or its level of significance.

A final decision was made to leave BROIDEF in and to avoid any direct use of the estimated beta coefficient. An intermediate model formulation included a linear time trend variable, but the sign on BROIDEF was still negative and it was still insignificant. Part of the problem could be in the variable itself. The BROIDEF series is a series of deflated prices for ready-to-cook broilers. In recent years, much of the consumption in poultry has switched to the "further processed" products, and the series used here may not be picking up any increased

Table 9. Summary Statistics and Estimated Beta Coefficients for a Preliminary Quantity-Dependent Model, Beef, 1960-87

Dependent Variable	BEEFCON
Standard Error of Regression	1.269
R-squared	.569
Adjusted R-squared	.540
F Statistic (16, 95)	19.600
Probability Value for F	.000
Mean Squared Error	167.488
Durbin-Watson Statistic	.325

Variable	Coefficient	T-Ratio	Prob > T
INTERCEPT	9.142	3.690	.000
BEEFDEF	-.0136	-2.168	.031
PORKDEF	.0463	5.886	.000
BROIDEF	-.0109	-.733	.472
DEFINC	.00067	3.468	.001
QDUM2	.00797	.023	.930
QDUM3	.25855	.759	.456
QDUM4	-.02722	-.079	.896

acceptability of the value-added cuts of chicken as substitutes for beef.

As would be expected, the use of the yearly shift dummies generates very strong R-square measures. The large t-ratios indicates each of the implied models for 1977 through 1987 has an intercept significantly different from the overall intercept of 17.274 pounds. The first year for which shift dummies were significant was 1977, with a coefficient of -1.062. The absolute level of the coefficients then increases steadily to a level of -9.002 in 1987. Major shifts in the underlying demand surface were apparently occurring that were not being explained by the traditional "shifters" such as income and changes in prices of potential substitutes.

The quantity-dependent specification provides a more traditional approach to estimation of elasticity parameters. At the mean levels of BEEFCON and BEEFDEF, the -.0417 beta coefficient for BEEFDEF generates a demand elasticity estimate of -.548. This estimate is smaller in absolute value than the -.67 used earlier for demonstration purposes. It does fit the often voiced hypotheses in recent years that beef demand is becoming more inelastic. Note that the parameter is much smaller than that generated by the "inverse" approach from the price dependent model. As noted earlier, the estimate generated by price dependent models is best viewed as the lower bound (in terms of more negative estimates). The estimate of -.548 indicates one percent quantity changes will bring price changes of almost two percent in the opposite direction.

At mean levels of the respective variables, this model generates an estimate of the cross elasticity for pork of -.196. The income elasticity estimate is .727. Both estimates are generally consistent with expectations and with other published findings. The .196 estimate for pork suggests pork is not a strong substitute, with a one percent change in deflated pork prices prompting a .196 percent change in beef consumption in the opposite direction at constant beef prices.

The discussion surrounding the use of yearly shift dummies via the price dependent model need not be repeated here. It is sufficient to note that the underlying demand surface has shifted since the late 1970s, but we do not fully understand why. The shifts are not explained by the traditional economic forces.

The quantity-dependent model tends to confirm earlier inferences. There was apparently a shift around 1977 that continued to develop during the 1980s. The quantities of beef consumers

Table 10. Summary Statistics and Estimated Beta Coefficients for the Final Quantity-Dependent Model, Beef, 1960-87

Dependent Variable	BEEFCON
Standard Error of Regression	.449
R-squared	.952
Adjusted R-squared	.942
F Statistic (16, 95)	101.903
Probability Value for F	.000
Mean Squared Error	18.744
Durbin-Watson Statistic	1.567

Variable	Coefficient	T-Ratio	Prob > T
INTERCEPT	17.274	16.319	.000
BEEFDEF	-.0417	-8.736	.000
PORKDEF	.0199	5.826	.000
BROIDEF	-.0397	-4.080	.000
DEFINC	.00153	15.773	.000
QDUM2	-.0801	-.662	.509
QDUM3	.424	3.511	.001
QDUM4	-.284	-2.324	.022
DUM77	-1.062	-3.876	.000
DUM78	-1.534	-5.980	.000
DUM79	-2.120	-5.956	.000
DUM80	-2.499	-7.376	.000
DUM81	-3.530	-11.566	.000
DUM82	-4.403	-14.199	.000
DUM83	-4.841	-15.668	.000
DUM84	-5.479	-16.416	.000
DUM85	-6.275	-17.302	.000
DUM86	-7.296	-18.836	.000
DUM87	-9.002	-23.853	.000

were willing to accept at a particular schedule of prices declined to an extent that cannot be explained by traditional economic forces. The appropriate conclusion is that a structural change in demand for beef did occur in the late 1970s and early 1980s, and the analysis reported here indicates the problems persisted through 1987.

Out-of-Sample Test: Beef

Table 11 records predicted prices and per capita consumption levels for the four quarters of 1988. Actual deflated prices and quarterly per capita consumption levels are shown with predicted levels and prediction errors, ( )'s, for the price dependent and quantity dependent models.

In percentage terms, the largest prediction errors are 7 percent and 5.7 percent for the price-dependent and quantity dependent models for 1960-87. The average error would be substantially smaller, of course.

One of the difficulties in using yearly shift dummies emerges in the out-of-sample tests. There is no basis for knowing what "shift" coefficient should be used for 1988.

In testing the performance of the model for 1988, the estimated beta for DUM87 was used. The accuracy of the predictions for both price and quantity and the presence of both positive and negative errors suggests the 1987 model performs well for 1988. The out-of-sample tests thus indirectly test the earlier inference that demand for beef consolidated during 1988, and the pattern of annual decreases had come to an end.

Table 11. Out-of-Sample Tests for the Price Dependent and Quantity-Dependent Beef Models for 1988

Period	Deflated Retail Prices ($/lb.)	Predicted Deflated Prices (Actual-Predicted) ($/lb.)
1988.1	$2.118	$2.201 (-.083)
1988.2	2.165	2.150 (.015)
1988.3	2.174	2.199 (-.025)
1988.4	2.153	2.306 (-.153)
Period	**Per Capita Consumption (lbs.)**	**Predicted Per Capita Consumption (Actual-Predicted) (lbs.)**
1988.1	18.2	18.80 (-.60)
1988.2	18.5	18.35 (.15)
1988.3	18.7	18.60 (.10)
1988.4	17.3	18.14 (-.84)

It *is* true that the over-prediction errors, for both price and quantity, exceed the under-prediction errors in absolute value. But the errors are relatively small in statistical and economic terms, and are well within the range of what could occur due to lack of precision in data measurement. There is no pattern of sequential errors, either positive or negative, to suggest the model completely "misses" the level of demand for beef in 1988.

The out-of-sample tests provide no strong evidence of a shift in the demand surface for beef from 1987 to 1988. The results do, therefore, provide evidence in support of an hypothesis that the level of demand in 1988 was essentially the same as in 1987. There is no evidence from the tests that the decline in demand that were documented prior to 1988 were repeated in 1988.

Demand for Pork

Analysis of demand for pork across the 1960-1987 period was begun by specifying a price dependent model. PORKDEF, the dependent variable, is deflated (1982-84 = 100) quarterly average retail pork price. Conceptually, it can be argued that quarterly supplies of pork are largely pre-determined by production decisions made prior to the quarter. If that is the case, price will adjust to quarterly supplies of pork for given levels of demand and adjust to any shifts in demand brought on by changes in income, price of substitute products, and any change in tastes and preferences.

A number of specifications were employed with varying combinations of the explanatory variables. The primary thrusts of the analysis were based on the earlier analysis and description of the pork sector. Beef and broilers were investigated as possible substitutes for pork. The relationship between pork price and income was analyzed. If changes in pork price cannot be explained by changes in income or changes in competing products such as beef and broilers, then some structural change involving preference shifts emerges as a possible explanation.

Any analysis of deflated pork prices must consider the high levels of correlation between possible explanatory variables. Table 12 shows the matrix of simple correlations for the variables that might be employed in the analysis.

The high levels of correlation between the broiler variables, both BROIDEF and BROICON, and the income variable (DEFINC) and the linear time-trend component (TIME) will prove troublesome. With the apparent problems of multicollinearity, it will be difficult to have both measures of the broiler sector and deflated income properly incorporated in the model. Since the broiler-related variables and the income variable are so highly correlated with

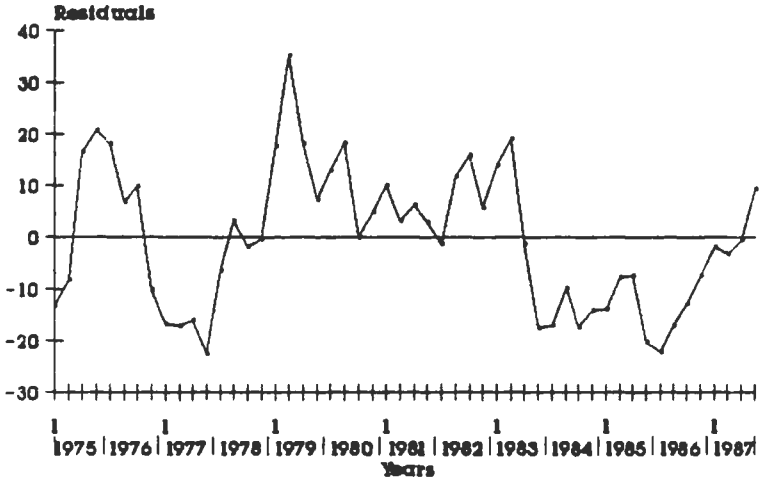
Table 12. Simple Correlation Matrix for Prices, Quantities, Income and Time: Pork Analysis

	PDEF	BDEF	BRDEF	DEFINC	PCON	BCON	BRCON	TIME
PORKDEF	1.00							
BEEFDEF	.61	1.00						
BROIDEF	.61	.50	1.00					
DEFINC	-.16	-.20	-.79	1.00				
PORKCON	-.59	-.06	-.28	.03	1.00			
BEEFCON	.41	-.38	-.20	.53	-.20	1.00		
BROICON	-.41	-.38	-.90	.91	.04	.25	1.00	
TIME	-.34	-.32	-.89	.96	.08	.36	.96	1.00

time, the TIME variable should be included as an intermediate step in determining what part of the influence being attributed to the broiler sector and/or to income might be related to time.

Paralleling the procedure employed with beef, Table 13 provides the statistics for a preliminary model that includes only the traditional economic variables and the seasonal price dummies. Figure 30 provides a plot of the residuals from 1975 through 1987, the period during which earlier discussion and analysis suggests shifts in pork demand apparently occurred.

Figure 30. Plot of Residuals for a Preliminary Price Dependent Model, Pork, 1975-87



The model shows obvious problems. R-square measures are better than the comparable preliminary model for beef, but the theoretically important beef consumption variable (BEEFCON) is insignificant. The Durbin-Watson statistic suggests major problems with autocorrelation. The residual plot in Figure 30 confirms the problems. A string of 17 negative residuals, many of them relatively large in absolute value, suggests the model is over-predicting pork price in 1977 and again during the early 1980s. It is interesting to note that performance during 1987 starts to improve, and this result may be evidence of the apparent improvement in pork demand that was identified in the earlier graphical exposition.

A number of alternative specifications was tried, and an overall attempt was made to model pork prices without relying on yearly shift dummies. The TIME variable was added to the specification shown in Table 13, but the BEEFCON variable was still insignificant and the Durbin-Watson statistic was at .663. There was no significant improvement in the adjusted R-square statistic. The beta coefficients on PORKCON, BEEFCON, BROICON, and DEFINC changed very little, and that stability is a positive result given the possible problems of multicollinearity introduced above.

A slope dummy was employed and related to the income variable (DEFINC) but it was not significant and the overall statistics improved very little. Various starting points for yearly shift dummies were then incorporated.

Table 14 shows the final model employed. Yearly shift dummies starting in 1977 are included. The shift dummy for 1979 (DUM79) was not significant, but was kept in the model on conceptual grounds and to maintain continuity in the shift-dummy structure. All seasonal dummies were retained for the same reasons.

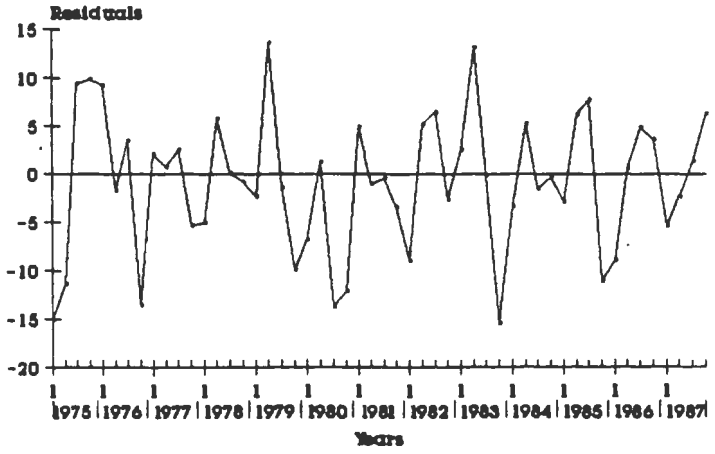
All explanatory variables have the expected signs, but BEEFCON is only significant at the .19 level. The problems of autocorrelation have disappeared, and the adjusted R-square statistic is up to .889. Figure 31 shows a plot of the residuals from 1975 through 1987, and the systematic time-related patterns are no longer present.

Table 13. Summary Statistics and Estimated Beta Coefficients for a Preliminary Price-Dependent Model, Pork, 1960-87

Dependent Variable	PORKDEF
Standard Error of Regression	12.5136
R-squared	.80589
Adjusted R-squared	.79282
F Statistic (7, 104)	61.6811
Probability Value for F	.000
Mean Squared Error	16285.3467
Durbin-Watson Statistic	.6940

Variable	Coefficient	T-Ratio	Prob > T
INTERCEPT	300.681	13.126	.000
PORKCON	-12.0728	-11.285	.000
BEEFCON	-.0699	-.061	.907
BROICON	-16.6895	-8.952	.000
DEFINC	.02502	6.151	.000
QDUM2	3.4183	.894	.37729
QDUM3	7.1195	1.732	.08237
QDUM4	10.6970	3.098	.00265

Figure 31. Plot of Residuals for the Final Price Dependent Model, Pork 1975-87



All the yearly shift dummies (except DUM79) indicate the intercept for models from 1977 through 1987 is significantly below the overall intercept of 346.178. The absolute value of the estimated beta coefficients tend to increase until 1986. The estimated beta for 1987, while departing from the overall intercept of 346.178, is smaller in absolute value than that for 1986. These results suggest that after a number of years during which the demand surface for pork shifted down, the pattern was reversed in 1987 and a year-to-year increase in demand was recorded from 1986 to 1987. When the out-of-sample test for 1988 is conducted using the shift dummy coefficient for DUM87 (or -44.84), another test of the hypothesized improvement in demand will be provided.

In an alternate specification that added time to the model shown in Table 14, the results were surprisingly positive and consistent. The t-ratio on the BROICON variable droped below 2.0 in absolute value, and the t-ratio for the BEEFCON variable increased to the 2.0 area. But the estimated beta coefficients on all the economic variables (PORKCON, BEEFCON, BROICON, and DEFINC) were quite stable, and lack of stability in alternative estimates of the beta parameters is one sign of serious problems with multicollinearity. The TIME variable was not included in the final model since it really does not explain anything from an economic viewpoint and apparently was not needed to "clean up" the estimation process and avoid the problems of time-related components changing the estimated beta coefficients on the economic variables.

Table 14. Summary Statistics and Estimated Beta Coefficients for the Final Price-Dependent Model, Pork, 1960-87

Dependent Variable	PORKDEF
Standard Error of Regression	9.1452
R-squared	.90629
Adjusted R-squared	.88935
F Statistic (17, 94)	53.4780
Probability Value for F	.000
Mean Squared Error	7861.6373
Durbin-Watson Statistic	1.4570

Variable	Coefficient	T-Ratio	Prob > T
INTERCEPT	346.178	17.919	.000
BEEFCON	-1.3198	-1.327	.18783
PORKCON	-14.8202	-16.711	.000
BROICON	-8.19587	-3.892	.00019
DEFINC	.01989	6.218	.000
QDUM2	-6.8639	-2.070	.04117
QDUM3	-2.8960	-.848	.39843
QDUM4	12.0369	4.746	.000
DUM77	-25.5588	-5.067	.000
DUM78	-14.4206	-2.724	.00769
DUM79	.8659	.142	.88716
DUM81	-17.0229	-2.620	.01025
DUM82	-22.3036	-3.044	.00303
DUM83	-24.3856	-3.467	.00079
DUM84	-44.7703	-6.099	.000
DUM85	-46.4742	-5.863	.000
DUM86	-52.2949	-6.272	.000
DUM87	-44.8423	-4.516	.00002

With time in the model, the t-ratios for the yearly shift dummies were not as large, and DUM79 was still insignificant. But the smallest t-ratio for the shift dummies other than DUM79 was 1.80 in absolute value (for DUM81), and the yearly shifts were clearly still necessary with a time-trend variable included. The 1986-87 pattern was still present. The DUM86 beta coefficient was -44.019, and it moved to -40.219 for the 1987 shift dummy (DUM87).

Overall, the model presented in Table 14 appears to be satisfactory. The adjusted R-square is near 89, and all theoretical expectations in terms of expected direction of impact on pork prices are met. With the time trend apparently not a major problem, elasticity parameters can be estimated with a reasonable degree of confidence.

The price flexibility parameter for pork is -1.142 at the mean levels of PORKDEF and PORKCON. Inverting, we would generate an estimate of own-price elasticity of demand to -.876. As was discussed earlier in the beef section, this should be viewed as the lower bound on the estimate of demand elasticity for pork. At mean levels, the income flexibility parameter for pork is .960, suggesting pork prices are responsive to changes in income. A 1 percent change in income brings a .96 percent change in pork prices in the same direction, all other factors held constant.

The beta coefficients for BEEFCON and BROICON allow estimation of cross-price flexibility parameters. At the mean levels of BEEFCON and PORKDEF, the cross price flexibility parameter is -.134. A 1 percent increase in per capita beef consumption is associated with a .134 percent change in pork prices in the opposite direction.

For broilers, the cross-price flexibility parameter is estimated at -.415. This result suggests that changes in per capita broiler supplies exerts a much larger impact on pork prices than do changes in per capita beef supplies. Poultry, it appears, is viewed as a strong and competitive alternative to pork.

Pork demand apparently declined periodically during the late 1970s and through 1986 in a manner that is not explained by the traditional economic demand shifters. With the apparent exception of 1979, demand decreased each year through 1986. The price-dependent models tend to support the inference from the earlier graphical exposition that suggested pork demand consolidated and started to increase in 1987.

The modeling effort for a quantity-dependent paralleled that of the price-dependent analysis. Per capita pork consumption (PORKCON) was regressed on the income variable (DEFINC), the deflated prices of beef (BEEFDEF), and the deflated prices of broilers (BROIDEF). The seasonal dummies (QDUM2 -- QDUM4) were included to account for any seasonal pattern in pork consumption that is not explained by income and the prices of the substitute meats.

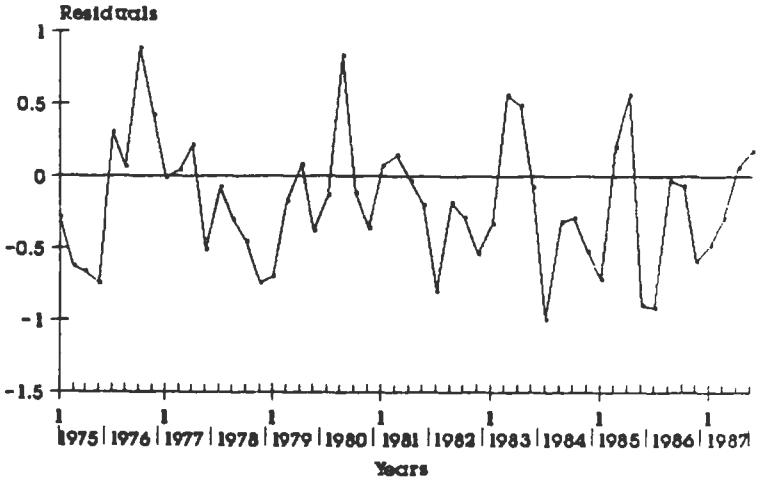
Table 15 provides the statistics for the preliminary model specification, and Figure 32 shows a residual plot for the 1975-87 period.

Overall statistical properties of the model reported in Table 15 suggest nearly 80 percent of the variation in PORKCON is being explained. Not all the explanatory variables are highly significant (eg, BROIDEF and DEFINC), but the signs are consistent with theoretical expectations. The major problem is with the Durbin-Watson statistic, which suggests significant problems of autocorrelation. With autocorrelation present in conjunction with the possible presence of multicollinearity, there is reason to be concerned over the effectiveness of efforts to correctly estimate the beta coefficients.

A shift dummy related to income was employed, but offered no significant improvement. The TIME variable was also included in an intermediate specification, but the Durbin-Watson statistic was still below 1.0 in absolute value. The time-related patterns in the residual plot of Figure 32 were not eliminated. Once again, it appeared that the dependent variable PORKCON was changing in ways that could not be adequately explained by the traditional economic demand shifters.

Table 16 records the final model with yearly shift dummies appearing from 1977 through 1987. The adjusted R-square is .878, and the signs on the economic variables are consistent with theoretical expectations. The BROIDEF variable is not statistically significant at traditional probability levels, but is retained in the model on conceptual grounds.

Figure 32. Plot of Residuals for the Preliminary Quantity Dependent Model, Pork, 1975-87



The results surrounding the broiler price variable suggest inconsistency with the price-dependent model for pork, but that may not be the problem. Pork prices were influenced by changes in per capita broiler consumption (Table 15), but broiler prices apparently do not significantly influence pork consumption over time. This finding may be due to the nature of the BROIDEF series. If the prices of the further processed cuts of chicken were incorporated, the results might well be different.

Figure 33 provides a residual plot for 1975-87 for the final model. The time-related patterns that persisted in the residuals until the yearly shift dummies were incorporated have disappeared. The Durbin-Watson statistic shown in Table 16 no longer suggests the presence of autocorrelation.

All the intercept shift dummies (DUM77 -- DUM87) confirm a statistically significant decrease from the overall intercept of 16.801. Absolute magnitudes of the estimated beta coefficients trend higher from 1980 through 1984 before varying around -2.6. The coefficients for 1986 and 1987 (for DUM86 and DUM87) provide limited confirmation of the earlier inference that demand for pork recorded a year-to-year increase from 1986 to 1987. Once again, the out-of-sample tests for 1988 will provide additional evidence on this tentative conclusion.

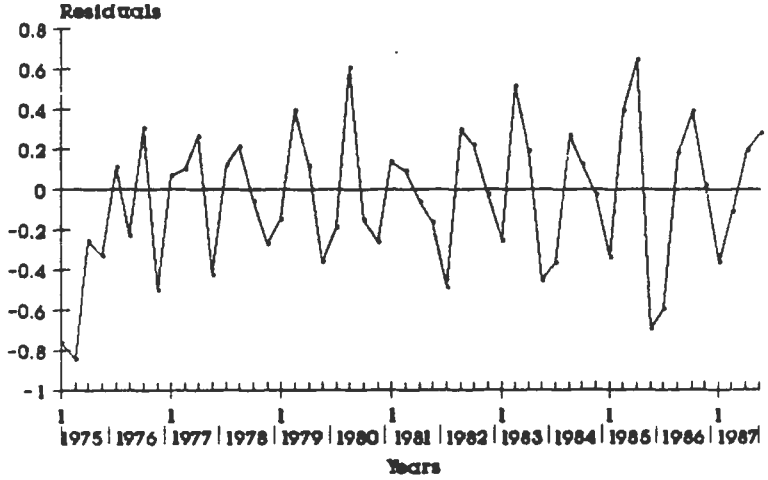
At the mean levels of PORKCON and PORKDEF, the -.0622 coefficient on PORKDEF generates an estimate of demand elasticity for pork of -.807. This estimate is slightly higher than some published estimates for pork, and is only slightly smaller in abso-

Table 15. Summary Statistics and Estimated Beta Coefficients for a Preliminary Quantity-Dependent Model, Pork, 1960-87

Dependent Variable	PORKCON
Standard Error of Regression	.6218
R-squared	.80668
Adjusted R-squared	.79367
F Statistic (7, 104)	61.9963
Probability Value for F	.000
Mean Squared Error	40.207197
Durbin-Watson Statistic	.8743

Variable	Coefficient	T-Ratio	Prob > T
INTERCEPT	14.8075	12.198	.000
BEEFDEF	.0289	9.426	.000
PORKDEF	-.0512	-13.271	.000
BROIDEF	.0137	1.877	.060
DEFINC	.00014	1.526	.126
QDUM2	-.9322	-5.594	.000
QDUM3	-.8454	-5.065	.000
QDUM4	.9717	5.784	.000

Figure 33. Plot of Residuals for the Final Quantity Dependent Model, Pork 1975-87



lute value than the estimate derived from the price-dependent model (-.876).

The estimate of income elasticity from the model in Table 16 is .323. This estimate is relatively small compared to that for beef, for example, and is somewhat smaller than most published estimates. It suggests a 1 percent increase in income would be associated with only a .323 increase in per capita pork consumption, all other forces held constant.

Since the estimate of the beta coefficient is sensitive to problems of high levels of correlation between and among the explanatory variables (multicollinearity), this issue is pursued in more detail below.

The coefficients for BEEFDEF and BROIDEF provide estimates of the cross elasticity with pork prices of .369 and .055 respectively. The .055 for broilers is relatively small, and should be used with caution given the possible problems with the data series (ready-to-cook broiler prices only), the lack of significance of the variable, and the high levels of correlation with other explanatory variables shown in the earlier correlation matrix.

Given the high correlation between DEFINC and BROIDEF and the high levels of correlation between both and the time-trend variable, the model shown in Table 16 was reestimated with TIME included. All model results were stable except for DEFINC and BROIDEF. The coefficient for DEFINC increased from .000515 to .000953, and the coefficient for BROIDEF decreased sharply, from .00771 to .00209. The t-ratio on BROIDEF decreased from .962 to .243.

If the income elasticity were reestimated, it would increase significantly, but the cross elasticity coefficient for broiler prices would be even smaller. Techniques to attempt corrections for problems of

Table 16. Summary Statistics and Estimated Beta Coefficients for the Final Quantity-Dependent Model, Pork, 1960-87

Dependent Variable	PORKCON
Standard Error of Regression	.4779
R-squared	.89786
Adjusted R-squared	.87810
F Statistic (18, 93)	45.4197
Probability Value for F	.000
Mean Squared Error	21.242675
Durbin-Watson Statistic	1.6695

Variable	Coefficient	T-Ratio	Prob > T
INTERCEPT	16.8011	14.910	.000
BEEFDEF	.0213	4.194	.00006
PORKDEF	-.0622	-17.030	.000
BROIDEF	.0077	.962	.33838
DEFINC	.000515	4.977	.000
QDUM2	-.973922	-7.556	.000
QDUM3	-.785035	-6.100	.000
QDUM4	.886190	6.817	.000
DUM77	-1.12519	-3.858	.00021
DUM78	-1.17828	-4.315	.00004
DUM79	-1.06825	-2.819	.00588
DUM80	-1.13328	-3.142	.00225
DUM81	-1.42396	-4.382	.00003
DUM82	-1.81119	-5.486	.000
DUM83	-1.53025	-4.653	.00001
DUM84	-2.59025	-7.290	.000
DUM85	-2.54104	-6.581	.000
DUM86	-2.76013	-6.693	.000
DUM87	-2.54517	-6.335	.000

multicollinearity are available, but are beyond the level of analysis presented in this bulletin. Here, we can conclude that there are problems in attempting to model pork consumption in a single-equation framework and conclude (1) income elasticity is positive but relatively small, and (2) broiler prices -- when further processed chicken cuts are not represented -- have only a marginal impact on per capita pork consumption.

In spite of the problems in estimating the elasticity parameters, the overall conclusion regarding shifts in demand is solidly supported. Demand for pork decreased periodically from 1977 through 1986 in a manner that is not explained by the traditional economic demand shifters. Late in the period, in 1987, there is evidence that the declines had come to an end and that the demand for pork was stabilizing at a level significantly below that which had prevailed prior to 1977.

Out-of-Sample Test: Pork

Table 17 provides estimates for the four quarters of 1988, with "prediction errors" shown in ( )'s.

The largest prediction error for the price-dependent model is 5.9 percent (quarter 4), and the largest error for the quantity-dependent model is 2.8 percent (quarter 3). These results suggest the models using the 1987 shift dummy coefficient do a reasonable job of "predicting" the 1988 price and quantity data. The absolute magnitude of the errors offers limited support to the earlier inference that demand for pork recorded a year-to-year increase from 1987 to 1988.

It is important to recognize that the sign and the magnitude of the prediction errors provide an indirect test for any year-to-year shift that is preference related. Any increase in demand associated with rising real incomes during 1988, higher beef prices,

Table 17. Out-of-Sample Tests for the Price Dependent and Quantity-Dependent Pork Models for 1988

Period	Deflated Retail Prices ($/lb.)	Predicted Deflated Prices (Actual-Predicted) ($/lb.)
1988.1	1.58	1.58 (0)
1988.2	1.57	1.54 (.03)
1988.3	1.56	1.51 (.05)
1988.4	1.49	1.56 (-.07)
Period	**Per Capita Consumption (lbs.)**	**Predicted Per Capita Consumption (Actual-Predicted) (lbs.)**
1988.1	15.4	16.61 (-.11)
1988.2	15.0	14.74 (.26)
1988.3	15.6	15.17 (.43)
1988.4	17.1	17.27 (-.17)

etc. may be completely accounted for by the economic variables in the set of explanatory variables -- DEFINC, BEEFDEF, and BROIDEF. A set of prediction errors for 1988 that was totally positive and relatively large in absolute value would confirm a year-to-year shift that is not accounted for by the traditional demand shifters. Thus, the presence of one or more negative error terms, which indicates the model over-predicted, in no way invalidates the inferences from the earlier graphical and elasticity framework analyses that suggest demand for pork staged a year-to-year increase in 1988.

The price and quantity-dependent models for the 1960-87 period predict 1988 price-quantity relationships accurately in the simple out-of-sample tests. The tests provide limited evidence in support of an hypothesis that suggests demand for pork increased from 1987 to 1988 at a level that is not totally explained by the influence of traditional economic "demand shifters". If expost analysis confirms that this was in fact the case, it would appear that a preference shift toward pork could have occurred.

Demand for Lamb

Modeling the demand for lamb is difficult for a number of reasons. The most important revolves around the issue of date availability. The USDA stopped reporting retail lamb prices in 1981, and there is no consistent price series available, either public or private.

Wholesale lamb prices are available, but use of wholesale prices creates analytical and conceptual problems. Consumers react to retail prices. With the tendency for retail prices to be "sticky" and change very little in the short run, the wholesale-retail price spread varies with wholesale prices. If the spread were constant, of course, the wholesale series could be effectively employed because variation in wholesale prices would mirror variation in the unreported retail prices.

One approach is to predict the wholesale-retail price spread and generate a retail price series using the wholesale price data. But this adds an element of error to the process, and the approach was not used in the analysis reported here. Instead, the retail prices through 1980 were integrated with wholesale prices for 1981-87 and shift dummies were employed to account for the abrupt change in price levels in 1981. Obviously, being forced to generate a price series in this manner complicates the analysis.

Other problems evolve because of the nature of the industry. Lamb is not available in all markets, tends to be consumed on a regional basis by ethnic groups, and price-quantity relationships for lamb

cannot be influenced by the traditional economic forces that act on beef, pork, and chicken. Since per capita disposable income is a "national" number, there is reason to speculate that regional consumption of lamb does not respond in the traditional way to changes in income. The same issue arises for the competing meats. Prices of beef, pork, and chicken may not impact on lamb consumption in the theoretically expected manner.

The nature of the per capita consumption data for lamb presents another problem. The levels are very small on a quarterly basis (less than 1 pound) and it is not unusual to see .4 pounds reported as the per capita consumption (actually, a "disappearance" number) for 5 to 6 consecutive quarters.

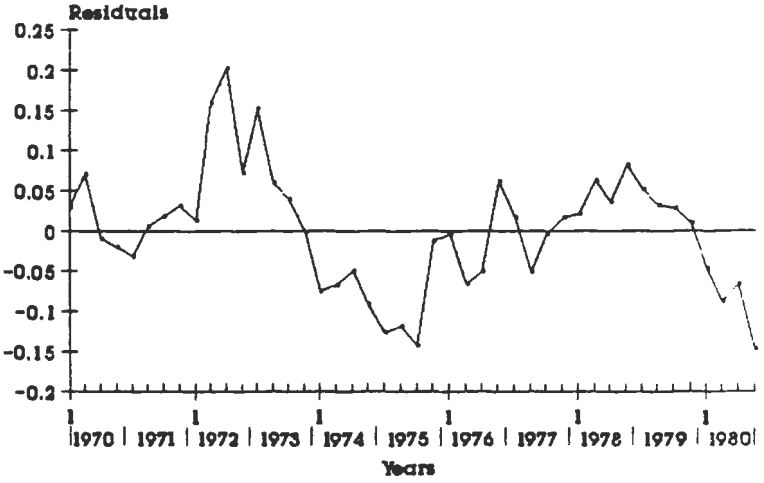
Given the problems with price series, lamb demand was analyzed only with a quantity-dependent specification. The 1970-80 period, a period during which retail prices were reported, is analyzed separately and then the 1970-87 period is analyzed by integrating the retail and wholesale price series.

Data and market availability issues complicate analysis of demand for lamb. Parameters generated from modeling efforts should be used with caution and with the shortcomings of the data clearly in mind.

Table 18 reports a correlation matrix that suggests problems of multicollinearity will be present. Across the 1970-80 time period, the LAMBDEF variable (deflated retail lamb prices) is highly correlated with the income variable (DEFINC) and the linear time-trend variable (TIME). From earlier developments, it is known that DEFINC and TIME are highly correlated, and that the deflated prices for the other meats (BEEFDEF, PORKDEF, BROIDEF) are often highly correlated. *A priori,* there are reasons to expect difficulties in properly allocating influence on lamb consumption across the price variables when PORKDEF and BROIDEF, for example, show a simple correlation of .74.

Table 19 shows the statistical results of a preliminary model for the 1970-80 time period, and Figure 34 provides a plot of the residuals. The anticipated problems are clearly present when the economic variables and the seasonal dummies are employed as explanatory variables. None of the prices for potential competing meats show a significant relationship with LAMBCON, and the income variable is negative and significant. The Durbin-Watson statistic indicates problems of autocorrelation, and the systematic time-related patterns are clearly present in the residual plot. The LAMBDEF variable does show the expected negative coefficient, but is not statistically significant.

Figure 34. Plot of Residuals for the Preliminary Quantity Dependent Model, Lamb, 1970-80



In attempts to generate a more workable model, the impact of the time-trend in the LAMBCON series continued to emerge as a complicating factor. In the earlier graphical expositions, it was clear that per capita consumption of lamb has trended consistently lower across the past two decades, especially during the 1970s.

As a general rule, any measure of time should be included in a model only as a last resort. In this particular instance, the influence of time on the LAMBCON dependent variable was so dominant that it required special attention. Either "time" had to be incorporated into the model, or the data would have to be "filtered" to remove the influence of the obvious linear time trend. Otherwise, potential explanatory variables such as DEFINC showed a negative sign in all model specifications, and the strong negative correlation between DEFINC and LAMBCON blocked any effort to isolate the underlying relationship between income and lamb consumption. Similar problems emerged with the BEEFDEF, PORKDEF, and BROIDEF variables.

Alternative specifications incorporated various combinations of the economic explanatory variables with and without the TIME variable in the model. Estimates of the important beta coefficient for LAMBDEF were monitored for stability across the various specifications. It developed that so long as TIME was incorporated as an explanatory variable, the estimated beta coefficient for LAMBDEF was stable around the -.001 level.

Efforts to isolate and measure a relationship between LAMBCON and explanatory variables such as DEFINC, PORKDEF, and BROIDEF were unsuccessful. The coefficient on each of the three was typically negative. With TIME not included, the relationships tended to be negative and statistically

Table 18. Simple Correlation Matrix for Prices, Quantities, Income and Time: Lamb Analysis

	LAMBCON	LAMBDEF	BEEFDEF	PORKDEF	BROIDEF	DEFINC	TIME
LAMBCON	1.000						
LAMBDEF	-.745	1.000					
BEEFDEF	-.294	.450	1.000				
PORKDEF	-.162	.396	.284	1.000			
BROIDEF	-.226	-.088	.259	.742	1.000		
DEFINC	-.836	.849	.431	.222	-.159	1.000	
TIME	-.902	.770	.334	-.048	-.439	.872	1.000

significant. With TIME included, the relationships tended to be negative and the t-ratios were very small, often near zero in absolute value.

The exception was the BEEFDEF variable. It tended to show the expected positive sign, especially when TIME was included to pick up the time-trend component in LAMBCON.

Table 20 shows a final and quite simple model. The seasonal dummies are not included. There was never evidence of a seasonal pattern in LAMBCON, but the nature of the data and the lack of precision in measurement would have suggested that result. A glance at the Durbin-Watson statistic indicates autocorrelation is still present, but none of the specifications solved that problem. Much of this finding may be due to the measurement of the LAMBCON variable. It was .4, for example, from quarter 2 of 1977 through quarter 3 of 1980. As expected, efforts to effectively analyze LAMBCON proved very difficult.

At the mean levels of LAMBCON and LAMBDEF, the demand elasticity parameter is estimated at -.523. Given the stability of the beta parameter for LAMBDEF across alternative specifications (with TIME in the model and excluded), reasonable confidence can be placed in this estimate for the 1970-80 period. If it is in error in any direction given the evidence of various specifications of the model, it is too large in absolute value.

> **The demand for lamb during the 1970-80 period was not responsive to the traditional economic forces. Per capita consumption was measured with a low level of precision, but appears to respond primarily to lamb prices and, marginally, to beef prices. The demand during the period was apparently quite inelastic with the elasticity parameter estimated in the -.5 area.**

Analysis of the extended 1970-87 period revealed some of the same conceptual and modeling problems that were encountered in the 1970-80 period. The integrated price series, employing wholesale prices from 1981 through 1987, appeared to be at least marginally acceptable when the 1981 shift was picked up by a shift dummy variable. Table 21 provides the results of a preliminary run, and Figure 35 plots the residuals from the model. LAMBDEF1 is the integrated price series. DATADUM is a 0-1 dummy variable that takes the value 0 from 1970 through 1980, the value 1 from 1981 through 1987.

Autocorrelation is clearly present, and the model is replete with problems. Signs on DEFINC, BEEFDEF, and PORKDEF are not consistent with theoretical expectations. The seasonal dummy variables suggest there is no strong seasonal pattern.

A number of specifications were employed. The time-trend component was again a dominating influence. Alternative yearly shift dummies were employed in an attempt to isolate any shift in the demand surface in the late 1970s and 1980s that was not being explained by the traditional economic variables. When the time-trend variable was excluded, the 1980-83 period tended to show statistically significant and negative yearly shifts. Of course, the 1981 shift dummy would be expected to pick up the change in the level of the price series.

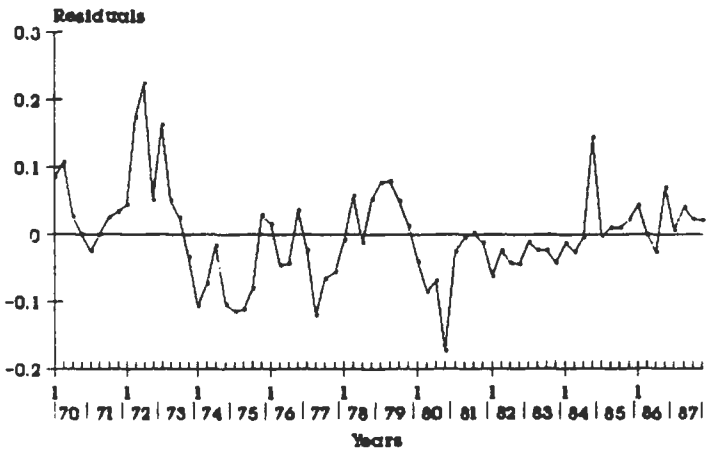
A simple model is shown in Table 22. The overall statistics are marginally acceptable. Autocorrelation will still be present, but the LAMBDEF1 variable showed enough stability across specifications to support reasonable confidence in the -.001 estimated beta coefficient. With TIME in the model, DEFINC is positive but is not statistically significant. None of the price variables -- BEEFDEF, PORKDEF, BROIDEF -- showed positive signs after TIME was included to pick up the trend component. The positive coefficient on BROIDEF in Table 21 clearly came from the observed decreases in LAMBCON and BROIDEF across the time period, and the inclusion of time eliminated that apparent relationship.

Table 19. Summary Statistics and Estimated Beta Coefficients for a Preliminary Quantity-Dependent Model, Lamb, 1970-80

Dependent Variable	LAMBCON
Standard Error of Regression	.0840
R-squared	.7263
Adjusted R-squared	.6638
F Statistic (8, 35)	11.6137
Probability Value for F	.000
Mean Squared Error	.2469
Durbin-Watson Statistic	.5586

Variable	Coefficient	T-Ratio	Prob > T
INTERCEPT	2.27017	8.511	.000
LAMBDEF	-.00082	-.554	.583
BEEFDEF	.00037	.508	.614
PORKDEF	-.00036	-.347	.731
BROIDEF	.00138	.714	.479
DEFINC	-.00019	-3.833	.000
QDUM2	-.02259	-.624	.537
QDUM3	-.03084	-.853	.399
QDUM4	-.03118	-.820	.418

Figure 35. Plot of Residuals for the Preliminary Quantity Dependent Model, Lamb, 1970-87



The model in Table 22 shows negative and significant coefficients on DUM81 and DUM82. The finding for DUM81 is partly explainable by the shift in the price series, but the same explanation is not relevant for DUM82. This finding, and the tendency for DUM80-DUM83 to show negative and significant coefficients when TIME was not in the model, offers limited support to an inference that demand for lamb decreased with the other red meats during the early 1980s. Given all the data and analytical problems, this result should be used with caution, however.

At mean levels of LAMBDEF1 and LAMBCON, the demand elasticity parameter is estimated at -.511. The estimate is consistent with that from the 1970-80 time period, but emerges from an analysis that employs a wide range of prices due to the integrated price series.

Demand for lamb across the 1970-87 time period appears to have been quite inelastic. Modeling efforts are suspect due to data problems, but there is limited evidence of declines in demand in the early 1980s that could have been related to shifts in preference patterns. None of the traditional economic forces -- income and prices of potential substitutes -- appeared to have significant influence on demand during the period. Variation in per capita consumption are explained primarily by variations in lamb prices and time-related measures such as time trend and yearly intercept shifts.

Table 20. Summary Statistics and Estimated Beta Coefficients for the Final Quantity-Dependent Model, Lamb, 1970-80

Dependent Variable	LAMBCON
Standard Error of Regression	.0637
R-squared	.8204
Adjusted R-squared	.8069
F Statistic (3, 40)	60.9148
Probability Value for F	.000
Mean Squared Error	.1620
Durbin-Watson Statistic	.9204

Variable	Coefficient	T-Ratio	Prob > T
INTERCEPT	1.2978	7.760	.000
LAMBDEF	-.0009	-1.284	.206
BEEFDEF	.00025	.517	.608
TIME	-.00908	-7.661	.000

Demand for Broilers

Earlier analysis of the price-quantity scatter plots for broilers did not suggest the major demand problems in the 1980s that apparently prevailed in the red meats. Prior to 1980, it appears the industry was operating on or near a long-term demand surface. Per capita supplies increased, but consumers were willing to take the increases only at lower inflation-adjusted prices.

During the 1980s, the price-quantity scatter plots support an initial hypothesis that demand for broilers staged occasional year-to-year increases. From this perspective, demand for broilers was analyzed for the 1960-87 period with special attention to the 1975-87 period. Both price-dependent and quantity-dependent models were analyzed to allow examination of the consistency between the two alternative approaches to estimation of important elasticity parameters. Given the shorter production period, the conceptual arguments that quantity is largely predetermined by decisions prior to any particular quarter are perhaps less imposing for broilers than for alternative meats such as beef, pork and lamb.

Table 23 records the statistical summary and estimated beta coefficients for a preliminary price-dependent model. The traditional economic forces and the seasonal dummies are included as explanatory variables.

The model described in Table 23 and the residual plot for 1975-87 in Figure 36 do not show the prolonged periods of "shifts" that were apparent in beef and pork. For the model reported in Table 20, BROICON, BEEFCON, PORKCON, and DEFINC plus the seasonal dummies as explanatory variables generate an adjusted R-square of .92, a mean squared error of 4242, and a standard error of regression of 6.39. These statistical properties are certainly respectable.

Analysis of the residuals did reveal problems, however. There was a period of sustained negative residuals during the early 1980s and the Durbin-Watson statistic was at 1.2, suggesting the presence of autocorrelation. Given these findings, there was concern about the efficiency of the estimations for the beta coefficients and the model was reformulated. Yearly shift dummies were employed in an attempt to eliminate the problems of autocorrelation and to investigate any year-to-year shifts in the demand surface during the 1980s.

Table 24 presents a final model that includes shift dummies for the 1977-87 period. The overall statistical properties show only marginal improvement. The Durbin-Watson statistic is improved, however, and the residual plot in Figure 37 shows no persistent time-related patterns. Comparisons of the two models indicates estimates of the beta coefficients changed very little with the inclusion of the yearly shift dummies. Thus, estimates of elasticity parameters will not be significantly different.

Table 21. Summary Statistics and Estimated Beta Coefficients for a Preliminary Quantity-Dependent Model, Lamb, 1970-87

Dependent Variable	LAMBCON
Standard Error of Regression	.0734
R-squared	.7616
Adjusted R-squared	.7269
F Statistic (9, 62)	22.0071
Probability Value for F	.000
Mean Squared Error	.3336
Durbin-Watson Statistic	.8047

Variable	Coefficient	T-Ratio	Prob > T
INTERCEPT	2.15367	9.663	.000
LAMBDEF1	-.00206	-2.351	.02190
BEEFDEF	-.00062	-1.226	.22487
PORKDEF	-.00074	-1.142	.25804
BROIDEF	-.00259	2.101	.03972
DEFINC	-.00009	-3.938	.00021
QDUM2	-.01201	-.483	.63086
QDUM3	-.02888	-1.177	.24376
QDUM4	-.02334	-.906	.36828
DATADUM	-.42155	-2.585	.01211

Figure 36. Plot of Residuals for a Preliminary Price Dependent Model, Broilers, 1975-87

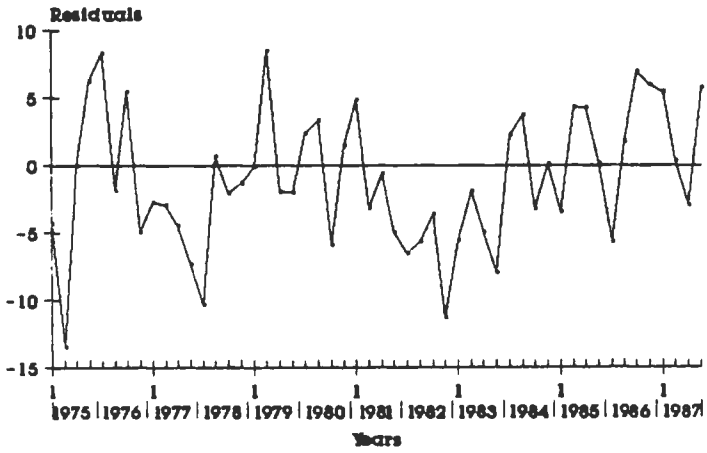
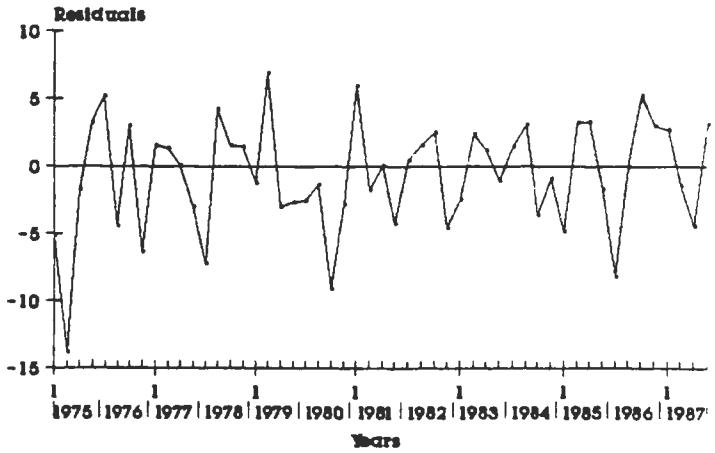


Figure 37. Plot of Residuals for a Final Price Dependent Model, Broilers, 1975-87



With the exception of DUM79, the t-ratios for all yearly shift dummies exceed 1.0 in absolute value. The shifts for 1982 and 1983 (DUM82, DUM83) are negative and highly significant. There is thus limited evidence that the price-dependent models for 1977 through 1987 would show an intercept below the 242.015 for the overall model. Examination of the estimated beta coefficients tend to confirm the apparent year-to-year increase in demand from 1983 to 1984. The intercept shift increased from -12.37 to -6.82, suggesting the demand surface shifted substantially during the 1983-84 period. There is no evidence of major shifts after 1984, but the out-of-sample tests for 1988 will provide an indirect test of

Table 22. Summary Statistics and Estimated Beta Coefficients for the Final Quantity-Dependent Model, Lamb, 1970-87

Dependent Variable	LAMBCON
Standard Error of Regression	.0560
R-squared	.8521
Adjusted R-squared	.8408
F Statistic (5, 66)	76.0466
Probability Value for F	.000
Mean Squared Error	.2069
Durbin-Watson Statistic	1.0911

Variable	Coefficient	T-Ratio	Prob > T
INTERCEPT	1.27963	6.003	.000
LAMBDEF	-.00101	-7.079	.000
DEFINC	.000011	.371	.712
TIME	-.00889	-7.550	.000
DUM81	-.08804	-2.750	.007
DUM82	-.08895	-2.593	.011

any shift from 1987 to 1988. The scatter plots presented earlier suggested demand did in fact increase from 1987 to 1988.

Using the parameter estimates from Table 24, the price flexibility for broilers is estimated at 1.192 for mean levels of BROICON and BROIDEF. Taking the reciprocal, the estimate of demand elasticity is -.839.

Working with mean levels, the income flexibility coefficient is 1.187, suggesting deflated broiler prices have been responsive to changes in income. The cross price flexibility parameters are -.755 and -.541 for beef and pork respectively. Both parameter estimates indicate broiler prices are sensitive to changes in per capita beef or per capita pork consumption, all other factors held constant.

Overall, there is evidence that the level of demand for broilers was lower during the late 1970s and early 1980s than it was earlier in the 1960-87 analysis period. But the evidence is far less compelling than it was for beef and pork. With the possible exception of 1982 and 1983, variation in deflated broiler prices can be explained satisfactorily using the traditional demand shifters of income and per capita consumption of competing meats. Parameter estimates would be only marginally different than those generated by the final model which includes yearly shift dummies. Incorporating the shift dummies also confirms the earlier inference that broiler demand staged a year-to-year increase from 1983 to 1984.

The quantity-dependent models for broilers proved to be difficult in an analytical context. Observation of earlier graphical developments indicates that per capita broiler consumption, measured by the BROICON variable, has trended consistently higher over time. A positive trend is present for deflated per capita disposable income, DEFINC, and strong negative trends exist for deflated beef and pork prices, BEEFDEF and PORKDEF respectively. Thus, there are three theoretically important explanatory variables -- DEFINC, BEEFDEF, PORKDEF -- that are not only correlated with BROICON but with each other as well. For example, the simple correlation between BROIDEF and DEFINC was -.794, and the simple correlation between BROIDEF and PORKDEF was .609.

A simple correlation coefficient of .960 between deflated per capita disposable income or DEFINC and the time trend variable, TIME, raises major concerns about the use of any time trend measure as an explanatory variable. The multicollinearity problems that would exist between DEFINC and time suggests TIME should not be used in the model. Estimates of the beta coefficient on DEFINC would be suspect. Therefore, the modeling efforts proceeded with an objective of specifying to handle any time-related components not explained by the eco-

Table 23. Summary Statistics and Estimated Beta Coefficients for a Preliminary Price-Dependent Model, Broilers, 1960-87

Dependent Variable	BROIDEF
Standard Error of Regression	6.3870
R-squared	.92628
Adjusted R-squared	.92131
F Statistic (7, 104)	186.665
Probability Value for F	.000
Mean Squared Error	4242.5492
Durbin-Watson Statistic	1.2256

Variable	Coefficient	T-Ratio	Prob > T
INTERCEPT	232.102	19.851	.000
BEEFCON	-4.08193	-6.932	.000
PORKCON	-3.22039	-5.898	.000
BROICON	-15.3736	-16.156	.000
DEFINC	.0157769	8.048	.000
QDUM2	10.2633	5.256	.000
QDUM3	13.3903	6.383	.000
QDUM4	.246377	.140	.8598

nomic variables without using the TIME variable -- which should always be a last resort.

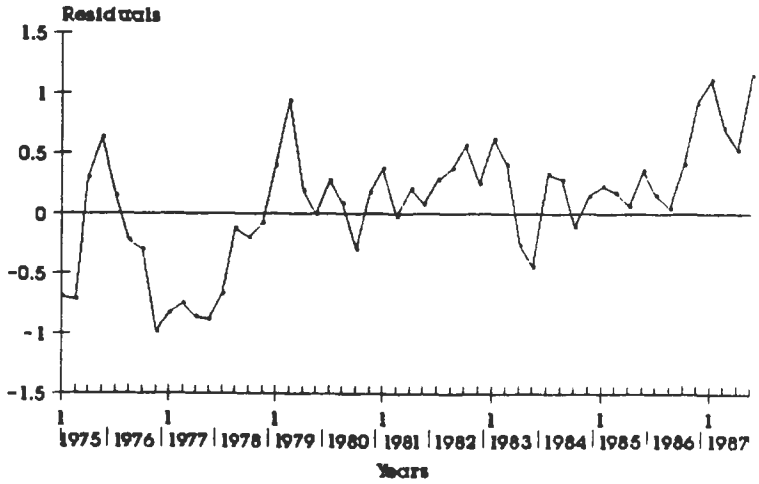
Table 25 presents the statistical properties of a preliminary model with the traditional economic variables and the seasonal dummies as explanatory variables. The R-square measures are high, but the model is not as effective as it looks on first glance.

With the strong and persistent trend in per capita broiler consumption, variation in the dependent variable is apparently easy to explain. But the signs on the estimated beta coefficients for both beef and pork prices are inconsistent with theoretical expectations. The Durbin-Watson statistic is at .55, indicating the presence of autocorrelation. The entire modeling process, and especially the estimates of the beta coefficients for BEEFDEF, PORKDEF, and DEFINC, must be considered suspect.

Figure 38 provides a plot of the residuals from 1975 through 1987. A string of negative residuals occurs in 1976-78, and a string of positive residuals occurs in 1981-83, suggesting per capita consumption was being underestimated during 1981-83. The last 13 residuals are all positive, again suggesting the model is under estimating the dependent series.

The time-trend variable, TIME, was added to the specification shown in Table 25 in an intermediate

Figure 38. Plot of Residuals for a Preliminary Quantity Dependent Model, Broilers, 1975-87



step to determine the impact of time. The signs on BEEFDEF and PORKDEF were still negative, the Durbin-Watson statistic improved only to .6074, and the t-ratio for the income variable, DEFINC, dropped to .558. The TIME variable showed a highly significant positive trend.

Problems associated with the high correlation between TIME and DEFINC were apparent in this

Table 24. Summary Statistics and Estimated Beta Coefficients for the Final Price-Dependent Model, Broilers, 1975-87

Dependent Variable	BROIDEF
Standard Error of Regression	6.1667
R-squared	.93788
Adjusted R-squared	.92665
F Statistic (17, 94)	83.4843
Probability Value for F	.000
Mean Squared Error	3574.678
Durbin-Watson Statistic	1.3785

Variable	Coefficient	T-Ratio	Prob > T
INTERCEPT	242.015	18.578	.000
BEEFCON	-4.0524	-6.041	.000
PORKCON	-3.8247	-6.396	.000
BROICON	-12.842	-9.044	.000
DEFINC	.01342	6.218	.000
QDUM2	7.4361	3.326	.00126
QDUM3	10.4711	4.548	.00002
QDUM4	.5035	.294	.76905
DUM77	-6.5759	-1.933	.0562
DUM78	-6.4402	-1.804	.07442
DUM79	-3.3498	-.816	.41643
DUM81	-6.9010	-1.575	.11859
DUM82	-14.7065	-2.976	.00371
DUM83	-12.3740	-2.609	.01056
DUM84	-6.8183	-1.378	.17161
DUM85	-7.3420	-1.374	.17284
DUM86	-6.8627	-1.221	.22519
DUM87	-8.8098	-1.316	.19144

intermediate step. There are instances when inclusion of a time-trend variable will resolve problems of estimating the other explanatory variables. The BEEFDEF and DEFINC variables, for example, would be fitted in the *presence* of the time-trend variable with the trend variable included to effectively remove the influence of time-related influences from estimates of the beta coefficients. But including TIME did not solve the autocorrelation problems, and other specifications were examined.

The residual plot showed systematic patterns, suggesting the demand surface was shifting in the late 1970s and into the 1980s. Attempts to generate an acceptable model without including yearly shift dummies did not prove acceptable, and shifts were included.

Table 26 shows the final model. All shift dummies from 1978 through 1987 were positive and significant. Absolute values of the estimated beta coefficients for DUM78 through DUM87 trended higher, indicating the models for each year would have an intercept above the overall intercept of 2.721. The R-square measures improved very little, but they were already high. The Durbin-Watson statistic moves up to 1.361, and no longer indicates major problems of autocorrelation in the residual or error terms.

The PORKDEF variable is positive and highly significant. The BEEFDEF variable continued to show a negative sign and is not significant, and is included solely on theoretical grounds. Multicollinearity problems involving PORKDEF, BEEFDEF, and DEFINC are clearly still present. It appears that the PORKDEF and DEFINC are the "stronger" variables and tend to dominate the BEEFDEF variable. Since the coefficient on

Table 25. Summary Statistics and Estimated Beta Coefficients for a Preliminary Quantity-Dependent Model, Broilers, 1960-87

Dependent Variable	BROICON
Standard Error of Regression	.5637
R-squared	.95501
Adjusted R-squared	.95198
F Statistic (7, 104)	315.368
Probability Value for F	.000
Mean Squared Error	33.04495
Durbin-Watson Statistic	.5518

Variable	Coefficient	T-Ratio	Prob > T
INTERCEPT	5.85242	.5318	.000
BEEFDEF	-.00385	-1.386	.16511
PORKDEF	-.00769	-2.202	.02825
BROIDEF	-.04079	-6.141	.000
DEFINC	.001106	12.983	.000
QDUM2	.865319	5.728	.000
QDUM3	.97281	6.429	.000
QDUM4	-.11395	-.748	.4624

BEEFDEF is extremely small, it will have little impact on the predictive power of the model.

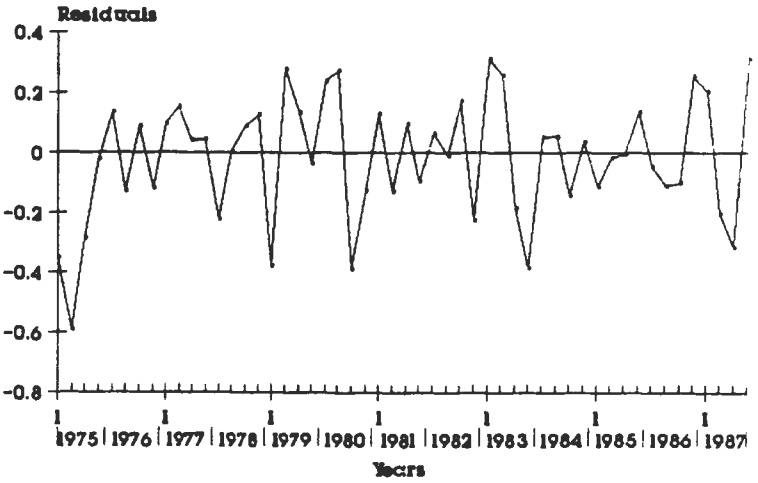
Continued concerns about the possible influence of time-trend prompted the addition of TIME to the model specification shown in Table 26. The primary objective was to examine the stability of the estimates of the beta parameters with TIME in the model.

With the yearly shifts included, TIME was no longer significant, showing a t-ratio of only .071. None of the estimated beta coefficients changed significantly. Even the coefficient on BEEFDEF was stable, changing only from the .000582 in Table 26 to .000573 with TIME included.

Figure 39 provides a plot of the residuals from 1975 through 1987. As would be expected, the systematic time-related patterns are no longer in evidence.

The beta coefficients in Table 26 provide an estimate of -.279 for the own-price demand elasticity for broilers at the mean level of BROICON and BROIDEF. This estimate suggests the demand for broilers is highly inelastic compared to beef and pork. It is worthy repeating that the per capita consumption of broilers includes the further processed cuts, but the price series does not. If all chicken cuts were reflected in the price series, we would expect the demand to be less inelastic. The -.279 suggests that, within a fairly narrow price range for ready-to-cook broilers over the 1960-87 period, consumers will adjust consumption levels very little in response to price changes.

Figure 39. Plot of Residuals for a Final Quantity Dependent Model, Broilers 1975-87



At mean levels, the income elasticity coefficient is estimated at .790. This estimate shows a strong relationship between income and chicken consump-

Table 26. Summary Statistics and Estimated Beta Coefficients for the Final Quantity-Dependent Model, Broilers, 1960-87

Dependent Variable	BROICON
Standard Error of Regression	.2771
R-squared	.9901
Adjusted R-squared	.9883
F Statistic (17, 94)	557.0045
Probability Value for F	.000
Mean Squared Error	7.2195
Durbin-Watson Statistic	1.3607

Variable	Coefficient	T-Ratio	Prob > T
INTERCEPT	2.72142	4.179	.000
BEEFDEF	-.00058	-.215	.830
PORKDEF	.00556	2.632	.009
BROIDEF	-.02590	-5.665	.000
DEFINC	.00082845	14.875	.000
QDUM2	.92950	12.44	.000
QDUM3	.88852	11.906	.000
QDUM4	-.02073	-.275	.783
DUM78	.46039	2.937	.004
DUM79	1.37718	6.303	.000
DUM81	1.80265	9.616	.000
DUM82	1.94150	10.215	.000
DUM83	1.94120	10.464	.000
DUM84	2.29266	11.844	.000
DUM85	2.50790	12.604	.000
DUM86	2.67952	12.442	.000
DUM87	3.28102	15.537	.000

tion, and may well reflect the impact of the further processed products, especially across the past 10 to 15 years.

The cross elasticity coefficients for pork is estimated at .109. Given the estimation problems surrounding the BEEFDEF variable, there is no viable estimate of the cross elasticity for beef. Pork does emerge as a relatively weak substitute for broilers.

The quantity-dependent model suggests demand for broilers was essentially constant until 1978. There is limited evidence, relating to the coefficients on yearly shift dummies, that the demand has worked higher during the 1980s. Much of any increase in demand can be explained by traditional economic demand shifters such as changes in income and changes in the price of pork. The coefficients on the yearly shift dummies, such as 3.281 for 1987, suggest some increase in the level of demand that is not completely and adequately explained by the traditional economic forces. There is, therefore, evidence of a preference or preference-related shift in favor of broilers during the 1980s.

Out-of-Sample Test: Broilers

The out-of-sample tests for the broiler models are shown in Table 27. The largest "prediction error" for the price-dependent model occurs in quarter 4, when price was over-predicted by 6.7 percent. The prediction errors for quarters 1-3 are smaller, and all are positive. In general, the price model using the shift dummy coefficient for 1987 (-8.8098) performs well but does show a tendency to predict prices too low. There is thus limited evidence that the demand surface for broilers increased from 1987 to 1988 for reasons not completely explained by traditional economic forces.

Table 27. Out-of-Sample Tests for the Price Dependent and Quantity-Dependent Broiler Models for 1988

Period	Deflated Retail Prices ($/lb.)	Predicted Deflated Prices (Actual-Predicted) ($/lb.)
1988.1	.643	.606 (.037)
1988.2	.688	.644 (.044)
1988.3	.804	.784 (.020)
1988.4	.749	.799 (-.050)
Period	**Per Capita Consumption (lbs.)**	**Predicted Per Capita Consumption (Actual-Predicted) (lbs.)**
1988.1	15.5	14.91 (.59)
1988.2	15.8	15.71 (.09)
1988.3	15.5	15.44 (.06)
1988.4	14.7	14.71 (-.01)

For the quantity-dependent model, the largest error is in Quarter 1. Per capita consumption was under-predicted by 3.8 percent. Estimates for 1988 are thus quite accurate, suggesting the fitted quantity-dependent model captures most of the forces that explain variation in per capita consumption. With the prediction errors positive in quarters 1-3 and larger in absolute magnitude than the negative error for quarter 4, the out-of-sample test again provides limited support for an hypothesis that demand increased from 1987 to 1988. This result would be consistent with the inference from the earlier scatter plot analysis that suggests demand increased in 1988.

The out-of-sample tests suggest the fitted models are efficient and effective. Prediction errors are small. Given the analytical and statistical difficulties in estimating the quantity-dependent model, the results of the out-of-sample tests are reassuring.

Both the price dependent and the quantity-dependent models provide limited evidence that demand for broilers increased during 1988. When 1989 data are available, application of the models using the 1987 shift coefficients will provide continuing tests of an hypothesis that demand is increasing for reasons not totally explained by income and prices of competing products. If prediction errors remain positive, reestimation of the models with intercept shift dummies for 1988 and 1989 will provide a means of quantifying the magnitude of any year-to-year shifts that are not being explained adequately by the traditional economic-based demand shifters.

Implications of Developments in Demand

In the introduction, the level of demand and/or changes in that level over time were identified as important determinants of the long-run economic viability of the livestock and meat section. In this sector, the results of the analyses will be related to changes in the industry and to the outlook for each of the meats as we look ahead to the 1990s. Coverage will be extended to how the models can be used in combination with basic graphical analysis and close monitoring of what is happening to guide industry actions and to help set program priorities.

The Beef Sector

The analytical models confirm the evidence in the scatter plots and other descriptive measures of demand. Demand for beef started to decline around 1977 and recorded significant year-to-year declines

each year through 1987. Evidence of consolidation appears in 1988, but there is no evidence that the level of demand has started to increase.

In the presence of largely constant nominal prices and declines in real prices that exceeded 30 percent, the beef sector was forced into major adjustments during the 1975-87 time period. Those adjustments occurred at the producer, processing, and retailing levels.

At the producer level, forced disinvestment was the key development. As the processing margins expanded in the face of price inflation that reached 10 percent or more in the early 1980s, the inability to pass any of the added costs up to the consumer put intense pressure on prices at the live cattle level. Inflation-adjusted prices of slaughter steers dropped sharply, and the pressure of those declines was extended to the feeder cattle and stocker cattle markets. As prices for light cattle and calves dropped below the costs of production, producers were forced to exit the industry and the U.S. cattle herd dropped from over 132 million head in 1975 to 99.5 million head in 1988 and 1989.

In coping with cost-price squeezes, rapid progress was made in productivity. Changes in cattle type in terms of genetic potential -- size, growth potential, yield of lean meat -- were made to allow the industry to increase output per head. Total beef production in 1987 and 1988 from a herd of less than 100 million head approaches the levels of the late 1970s when the herd was in the 110-115 million head range. Feeding more cattle to higher weights provided part of the increases in productivity, but there can be little doubt that increased production efficiency has been realized.

At the processing level, the declines in demand were a catalyst for changes in industry structure. Mergers and acquisitions brought a rapid increase in the level of concentration. In 1989, three firms are reportedly doing over 80 percent of the boxed beef business.

With the move to large size came the expected reductions in per unit costs. There are apparently economies of size in the slaughtering and breaking functions up to 300-400 head per hour, and further economies for multi-plant firms. The pressures to "get big and get cheap or get out" were intense during the period. Problems on the demand side were a major force in prompting the unparalleled developments in industry consolidation and concentration.

The shifts in beef demand are not adequately explained by the traditional demand "shifters" such as changes in income and changes in prices of substitute products. They came, apparently, in the form of adjustments in preference patterns by consumers who are increasingly health conscious and who value convenience in a constantly changing lifestyle. In looking ahead to the 1990s, it appears that the industry needs to focus attention on responding to those changing consumer needs and preferences.

A quick and widespread move to close trimming of fat cover is an example of what can be done to help position beef for the 1990s. Further progress is apparently needed in product development, packaging, pre-cooking, etc. to rebuild the image of beef in the eyes of a changing and increasingly discriminating consumer. As the industry turns back to herd building from a base that parallels the numbers of the early 1960s, per capita supplies will decline and the beef sector is sure to lose market share. It is doubly important, therefore, that demand at the consumer level be strong and resilient as the consumer is forced to react to reduced offerings and higher prices.

Models such as those presented here can be used to "predict" price and/or per capita consumption and to monitor progress on the demand side. In the presence of a constant monitoring of the price-quantity data and use of the basic elasticity framework, a set of "prediction errors" or residuals that show a consistent pattern will help measure what is happening to the level of demand. If prediction of the quarterly inflation-adjusted prices for 1989 using the price-dependent model for beef with the 1987 or an updated 1988 "shift" variable, show consistently positive residuals, we have evidence that the demand for beef in 1989 may have increased relative to 1987 (or 1988) for preference-related reasons.

Improvement in demand is essential to the sector. An aggressive program of product development, production efficiency, communication, and promotion will be necessary. If the venture capital and related research-development programs are not provided by the retailers or the packers, the producer groups should make sure the needed research and market development is done. If demand for beef cannot be turned around, its market share will continue to shrink and the industry will continue to contract and witness forced disinvestment at the producer and processor levels.

Demand for beef declined significantly from the late 1970s through 1987. Those declines have been a catalyst for dramatic changes in industry structure. Market share has been lost as the industry has contracted and absorbed forced disinvestment. To regain a more viable position in the 1990s, the decreases in demand for beef must be reversed. An aggressive and industry-wide program of research, product development, and promotion will be needed.

The Pork Sector

Developments in pork have paralleled what occured in beef, but the patterns across the 1975-87 period are less dramatic. The model results confirm the evidence in the scatter plots, and show year-to-year decreases in demand across the 1977-86 time period. Both the scatter plots and the elasticity framework, working through year-to-year changes in prices and per capita consumption, suggest demand for pork increased from 1986 to 1987. The demand models tend to confirm the inference. In the price-dependent model, for example, the coefficient on the "shift" variable for 1987 is -44.8 cents as compared to -52.3 for 1986.

The out-of-sample test for 1988 does tend to confirm an hypothesis that demand for pork is increasing relative to 1986 and 1987. It appears that the consolidation that started to develop in beef in 1988 developed at least a year earlier, in 1987, in pork.

The inability to pass increased costs up to consumers has had an impact on the pork sector. Sharply lower hog prices accompanied cyclical expansions in the early 1980s, and many producers were forced to exit the industry. As the inventories in marginal producing states declined, the industry has moved to a posture that shows a substantial part of the capacity in the key midwestern producing states.

Consolidation at the packing and processing levels has been substantial, and the cost-price squeezes have also been accompanied by moves toward new means of achieving vertical coordination. In some areas, many of the hogs are now being produced under contractual programs and there have been moves toward vertical integration with packers acquiring ownership of production programs. A primary motivation for these arrangements has come from the need to cut costs, increase efficiency, and gain control over the quantity flows and quality of the live hogs moving into processing.

Problems on the demand side have been a catalyst for change. Pressure on live hog prices is inevitable when the consumer will not pay higher prices and processing costs increase. The industry is moving toward the 1990s more highly concentrated and with a significantly different level of contractual activity than was the case in the late 1970s.

The problems facing the red meats and therefore the industry needs are the same for all the meats. Consumers have demanded less fat, a product that meets their perception of what is an appropriate part of their diets, and major advances in convenience. The convenience factor may prove to be extremely important when the industry looks back on this period of adjustment. Over 50 percent of the households now use microwaves and over 50 percent of the households have at least two persons working outside the home. In that lifestyle -- and those trends are expected to continue -- convenience is of paramount importance.

In looking ahead, it will be important for the pork sector to continue improvement in production and processing efficiency and to make every effort to boost the level of demand. As costs go up, the inability to pass those increases up to the consumer in the form of higher prices will eventually dictate reductions in costs or there will be forced disinvestment. It is a tautology that market share will go down if per capita supplies cannot be maintained or increased.

An aggressive program of research, market and product development, and promotion will be needed to continue and increase the apparent improvement in demand during 1987 and 1988. If the level of activity by retailers and/or packers in the product development area is not sufficient, then it is important that producer groups make sure the needed work is done.

Periodic decreases in demand for pork occurred across the 1977-86 time period. Those decreases have been a catalyst for changes in industry structure and in the mode of operation. More contractual and vertically integrated arrangements have emerged, and those trends are likely to continue. Forced disinvestment at the producer level has occurred in some areas. There is evidence that demand has started to improve during 1987-88, and the industry needs to continue aggressive programs to enhance that improvement and bolster the market position of its product.

The Lamb Sector

Data problems complicate analysis of demand for lamb, but the models and the scatter plots suggest that lamb faced essentially the same type of problem that confronted beef and pork during the late 1970s and early 1980s. The pattern of reduced domestic production is pronounced in lamb as the number of sheep trended lower until the mid 1980s. Lower lamb prices put pressure on producers, and a pattern of reduction in production levels was extended by the price pressure.

Changes in demand have been a catalyst for change in the lamb sector, but this industry faces a somewhat different set of challenges than those facing beef and pork. Per capita supplies -- and therefore per capita consumption -- are extremely small, and the product is not available in many sections of the domestic market. Imports are a significant part of the total product availability.

Application of any basic parameter, such as the demand elasticity parameter, will be complicated by the spotty product availability. The quantitative response to a price special on lamb, for example, may be partly a response to the price change and partly a function of product availability. Clearly, any empirical application of measures of demand or responsiveness must be used with care.

Abstracting from the problem of availability, the lamb sector faces important issues of market and product development. Appearance, the fat content and trim programs, and convenience will be important just as it is with the other red meats. An aggressive program of research, development, and promotion is needed to position the product to be more competitive.

The demand-related issues facing lamb are complicated by the problem of supplies and product availability. Total inventory is around 10 million head, and the early evidence of rebuilding inventory numbers and the breeding stock are present in 1989. As lambs are held back for breeding purposes, the supply of lamb available for consumption will be reduced. If this reduction is not offset by increases in imports, the already minimal per capita supplies will be reduced even further. Lamb thus faces a loss of total market share and problems of maintaining consistent supplies in those markets where the product has traditionally been available.

Problems on the demand side have been a catalyst in a contracting lamb sector, and improvement in demand is essential as a catalyst to boost the product into a more competitive position. Efforts are needed to generate or collect more complete data on retail prices to allow more effective monitoring of developments in demand. Graphical analyses and the analytical models developed in this analysis, given that their application is constrained by data problems, should be consistently updated to monitor change and any response to industry programs. A period of transition for the sector is inevitable as we move toward the 1990s and rebuild inventories. The strength or level of demand for lamb will be an important determinant of how well the industry copes with the transition.

Paralleling the contraction at the producer level has been consolidation in processing. A number of firms have exited the industry since the mid 1970s, and the remaining capacity is in the hands of a few large firms. As was the case with beef and with pork, this restructuring of the industry was perhaps an inevitable result of the demand problems and the concurrent cost-price squeeze at all levels of the industry. And paralleling the situation in beef and pork, it is not clear that the processors and/or retailers will provide market and product development that will be needed to revitalize demand for lamb. In this sector, it is likely that the producer trade groups will have to insure that the needed work will be done.

Lamb faced demand problems during the late 1970s and early 1980s. Data problems complicate analysis, but it appears there was a preference shift related to changing dietary habits and changing lifestyles. Complicated by the now small per capita supplies, the industry faces an important challenge in insuring that the market and product development work that is a necessary condition for economic growth will in fact be done.

The Broiler Sector

Demand has been a catalyst for change in the broiler sector as well, but the impacts have been different. In the mid 1980s, there is emerging evidence that periodic increases in demand have supported expanded production and industry capacity.

Before looking at the implications of demand for broilers in more detail, it is useful to consider exactly what was measured in this analysis. The price series for broilers is the "whole chicken" series, and does not capture the price dimensions of further processing. In recent years, the percentage of broiler production that is being further processed has increased dramatically. In discussing the analytical effort here, therefore, it is important to remember that prices for whole broilers may not parallel in 1:1 fashion prices for the value-added further-processed products.

Prior to the 1980s, it appears the broiler industry operated along a long-run demand curve that has prevailed since the 1960s. Increases in output were absorbed by consumers at lower inflation-adjusted prices, but the industry was able to bring enough technology into the system to continue increasing production at the lower real prices. Consolidation and the move to higher levels of vertical integration were undoubtedly also factors in industry-wide growth.

Missing across the late 1970s and 1980s is the declines in demand that plagued the red meats. Whether the broiler sector could have brought enough technology to offset 20 to 30 percent decreases in retail prices is debatable, but it did not have to face that problem. During a decade of transition and preference changes at the consumer level, it appears broilers did not receive the negative reactions that were extended to the red meats.

The scatter plots suggest increases in demand for broilers from 1983 to 1984 and again from 1985 to 1986. Those inferences are largely supported by the

modeling efforts. The yearly shift dummies show significant improvement in the beta coefficient for 1984, for example, in the price-dependent model, suggesting there were periodic year-to-year changes that were not completely explained by the traditional economic forces. It is important to keep in mind, however, that income is a "demand shifter". Rising real incomes during the 1980s, given a positive income elasticity for broilers, can and apparently did shift the demand surface for broilers up. The yearly shift dummies would have picked up more nearby shifts due to preference patterns, not shifts due to changes in income or in prices of substitute products.

Conceptually, the income elasticity for further processed poultry products should exceed that for broilers sold as whole chickens. If that is in fact the case, the industry was receiving a boost in demand for the further processed products, and that could explain the often large year-to-year increases in per capita supplies. Increases in demand for the further processed products would keep the entire sector viable and allow increases in per capita supplies to be absorbed without sharp decreases in broiler prices.

The out-of-sample tests for 1988 provided limited evidence of increases in demand that might be attributable to preference shifts. Most of the "forecast errors" for the models were positive for the quarterly predictions for 1988.

Looking ahead, it appears the poultry sector should continue its aggressive programs of product development, promotion, and brand-name differentiation. Large year-to-year increases in output may not be absorbed as easily during the 1990s as in the late 1980s, but the industry is in a "growth mode" at present. There are no obvious reasons why that growth cannot be extended into the 1990s, and efforts will be boosted by decreased per capita supplies and higher prices for the red meats as those sectors turn to building of breeding stock -- especially in beef and in lamb.

Prior to the 1980s, the broiler sector appeared to be operating along a single long-run demand surface. The sustained increases in output were based on technology, and the industry did not have to cope with decreases in demand. During the 1980s, there is evidence the demand for broilers is now increasing, and that demand will be a catalyst for continued growth.

Summary

During the 1960s and early 1970s, demand for the red meats was stable or increasing. Marketing decisions and longer range investment decisions could be made without major concern about shifts in demand as agents of change. That era of stability and growth came to an abrupt end in the late 1970s. Decreases in demand for the red meats and stable to increasing demand for poultry appear to have been the catalysts for industry-wide change and adjustment during the decade of the 1980s.

Starting in the late 1970s, apparently around 1977, demand for beef, pork, and lamb started declines that persisted through the 1986 year. An industry that was not accustomed to dealing with demand problems was implicitly being asked to recognize that problems did exist and make appropriate adjustments. The recognition and the adjustments have been slow to come, and the lack of reaction may well have been perpetuated by inconsistent and conflicting results coming out of the research community. A sampling of the research efforts is shown in the Selected References at the end of this bulletin. There has been little consensus as to whether demand problems have occurred.

The analysis reported here indicate that decreases in demand have in fact been a catalyst of change in recent years. In the red meats, the refusal of consumers to pay higher prices exerted pressure on live animal prices as the processors tried to gain relief from cost-price squeezes. Live animal prices were generally stable in nominal terms across the 1977-87 period, and recorded significant declines in inflation-adjusted terms. Since producers' costs were moving higher, forced disinvestment was the result. Breeding herds, especially in cattle and in sheep, moved sharply lower before stabilizing in the 1987-88 period.

The rapid consolidation and increases in concentration ratios of the 1980s have been, it could be argued, an inevitable result of the problems on the demand side. Moves toward fewer and larger firms captured significant economies of size, and reductions in processing costs eased some of the pressure on producer-level prices. It may be that the cattle herd, now showing signs of stabilizing around 99.5 million head, would have been forced lower without the changes in industry structure. Similar, if less dramatic, changes have occurred in the hog and sheep sectors.

Changes in structure are largely irreversible in the short run, and the nature of the red meat industry has been largely set for the 1990s. Large firms have market power, and tend to internalize exchange transactions and move to contractual procurement programs. Thus, while it could be argued that the consolidation has "saved" some of the capacity in the red meats, there are possible adverse implications to the production sector from that same consolidation. It is clear that producers and producer groups need to worry about, and try to correct,

problems in demand for the final product at the retail level.

The poultry sector emerges from the period of transition with a larger market share and poised for another era of growth. Thus, the changes emerging from shifts in demand for the meats is changing the market mix for the meats and those changes are likely to persist into the 1990s.

Improved demand has been a catalyst for growth for the meats, and it can be in the futures. More research is needed to document what is happening to demand, to insure the product being offered will fit the needs and preferences of the 1990s, and to position the particular sectors to be more competitive in the future. It is generally true that the beef, pork, lamb, and poultry sectors are competing for a relatively fixed per capita consumption capacity. But the sector that does not understand the nature of demand for their product will run the risk of losing market share during that competitive process. As suggested at the beginning, it will be what happens to the level of demand that will be an important determinant of the long-range viability of each of the meat subsectors.

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