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Analyzing the Seasonality of U.S. Meat Demand by Using Disaggregated Weekly Data

Thomas I. Wahl, Dermot J. Hayes, and David Hennessy*

Meat demand, and in particular the demand for meats in the U.S. retail market, has been the focus of numerous studies, including Blanciforti, Green, and King; Chalfant; Chalfant and Alston; Chavas; Christensen and Manser; Eales and Unnevehr; George and King; Heien; Huang; Huang and Haidacher; Moschini and Meilke; Nyankori and Miller; Pope, Green, and Eales; and Wohlgenant and Hahn. A detailed reading of this literature suggests that meat demand data have contributed more to the development of new econometric and theoretical methods than the methods have contributed to the understanding of the meat demand data. For example, the estimates for the own-price elasticities reported in these studies range from -0.11 to -0.96 for beef, -0.41 to -1.25 for pork, and -0.11 to -0.98 for chicken. In addition, there seems to be serious debate on whether beef, pork, and chicken are complements or substitutes.

Although no noticeable trend exists in the magnitude of the own-price elasticities or the signs of cross-price elasticities in the literature, there seems to be a trend toward increased sophistication in the methodologies used. In most cases, data quality has failed to keep up with the quality of the theory. Many economists are quite satisfied to report results from annual models of demand systems containing "beef," "pork," and "poultry"[1] and are somewhat disappointed when their industry colleagues ignore their work. In the meat packing industry, where the long run is one week, the number of products produced from one "beef" carcass can outnumber the number of annual observations used in typical studies.

In this paper, efforts are focused on improving data quality, by analyzing the demand for primal (or subprimal) cuts of beef, pork, and poultry and by using standard econometric procedures. The prices and quantities of these cuts are available on a weekly basis, but only at the wholesale level. Also, U.S. trade in these products is excluded; consequently, the claim that the estimated model reflects consumer preferences cannot be made (unless retail buyers are assumed to fully reflect the desires of their clients). Nevertheless, there are valid reasons for the use of wholesale cuts data.

First, assuming weak separability makes more intuitive sense at the wholesale level, where retail buyers tend to specialize in meats, than at the retail level, where the ordering of consumer preferences among meats may be influenced by the prices of close substitutes and complements for meats. Second, the data used in this study are actual prices and quantities, which may eliminate biases that can be introduced by aggregating over the hundreds of meat items offered at the retail level. Finally, the demand for beef cuts at the wholesale level is of greater interest to beef producers and processors than is the ultimate demand, especially when seasonal demand patterns are of interest. Retailers usually absorb much or all of the seasonal variation in supply and demand to avoid changes in retail meat prices. The opposite is true at the wholesale level, where relative and actual prices fluctuate dramatically over short time periods.

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[1]There are exceptions. Eales and Unnevehr use disaggregated data, and Wohlgenant and Hahn use monthly data.

This paper is structured as follows. First, the weekly data for 18 wholesale meat cuts is discussed. The results from an unconstrained Almost Ideal Demand System (AIDS) model of the same cuts are then presented. Next, the seasonal variation in demand for each cut is examined. And finally, the important results are summarized.

The Data

Each working day, the U.S. Department of Agriculture (USDA) collects information on the prices of wholesale beef and pork cuts. These prices and slaughter statistics are reported in USDA "bluesheets" and are summarized weekly in the USDA weekly market summary. Poultry prices and slaughter statistics are available in the USDA *Poultry Market News Report*. There are missing values in these publications, but these were obtained from the original, handwritten notes in the USDA archives. Nine beef cuts, eight pork cuts, and two poultry cuts were selected. The location and relative size of each of the selected beef and pork cuts are presented in Figures 1 and 2. For poultry, chicken leg and breast prices were used. The quantities of each of these meats were determined from the weekly annual slaughter statistics.[2]

Figures 3 through 10 present some trends in these selected price series. The most noticeable feature of these figures is the magnitude of seasonal price variations. These month-to-month price changes dwarf the annual trends and cyclical components. A noticeable difference exists between the patterns for the more expensive pork and beef cuts and the less expensive cuts. In general, the expensive cuts have shown a strong and stable upward tendency that is not evident in the less expensive cuts. The less expensive beef cuts seem to have reached their maximum level in 1978 and have since trended downward. There is some evidence of a strengthening of price for almost all the beef cuts in the last four years of the data. The less expensive pork cuts have exhibited a more stable overall pattern than have the more expensive pork cuts, whereas the effect of seasonal trends on the more expensive cuts is more pronounced. These seasonal patterns are not always correlated; in fact, there seems to be some reverse seasonality between high-quality cuts and low-quality cuts.

Figures 11 through 14 show the behavior of some selected price ratios. It is interesting to note that chicken breast prices have kept up with the prices of more expensive beef cuts and that chicken leg prices (not shown) have absorbed the reduction in overall chicken prices relative to other cuts.

The AIDS Model

To determine the seasonal shifts in the demand patterns, a demand equation that includes the relevant price and income effects for each cut must first be estimated. Failure to incorporate these price and income effects would cause seasonal effect parameters to be biased. The linear approximate AIDS (LA/AIDS) of Deaton and Muellbauer has many desirable properties for our purposes. The system's theoretical properties are said to be excellent (see Deaton and Muellbauer 1981), and its functional form has become very well known in the agricultural economics literature. In addition, the system is linear in prices and expenditures and can be estimated on an equation-by-

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[2]Steer, heifer, and hog carcasses were assumed to be cut in a way that consistently produces the relative percentages shown in Figures 1 and 2.

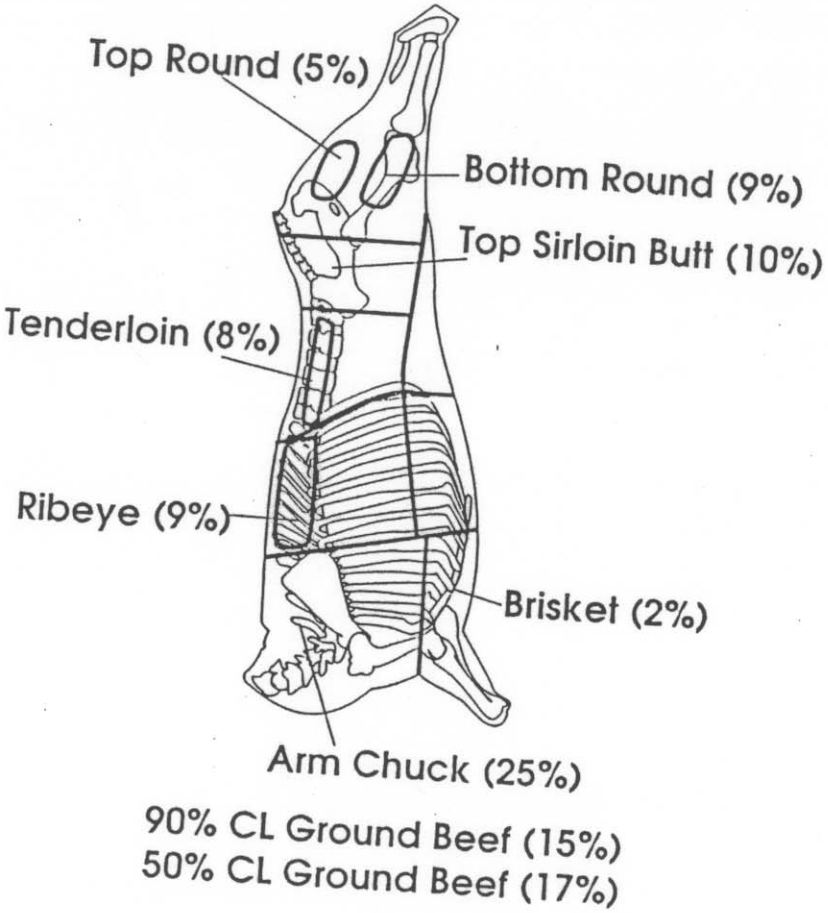

Figure 1. Schematic representation of the relative sizes and locations of the beef cuts used.

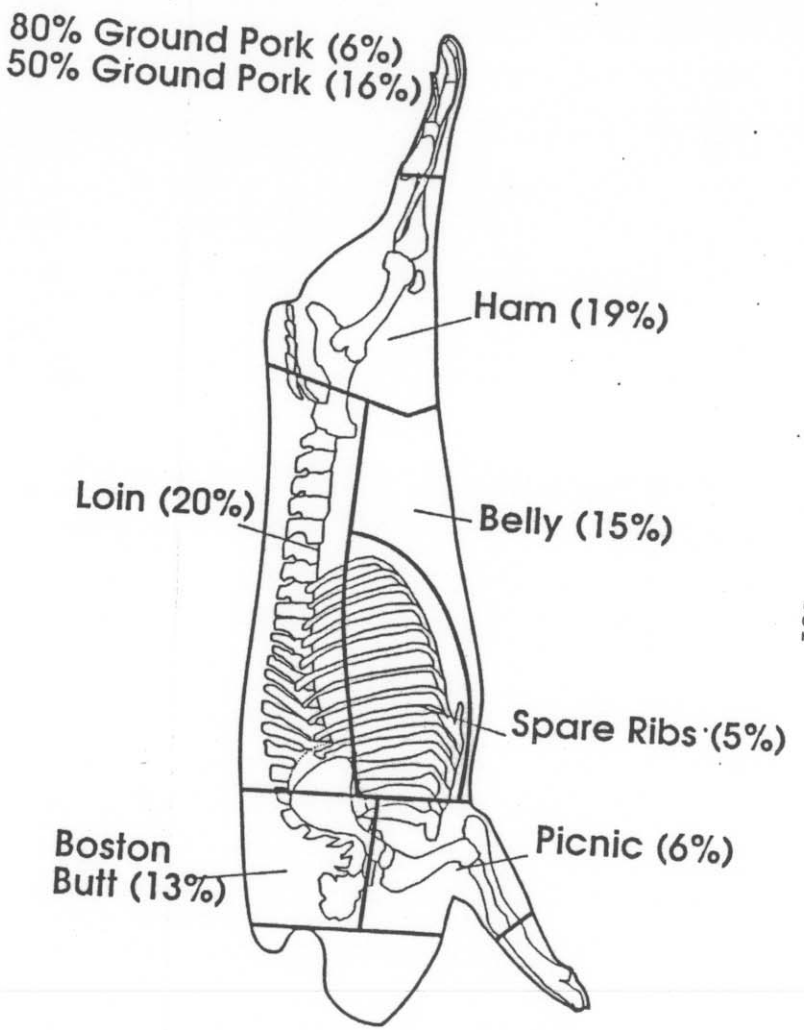

Figure 2. Schematic representation of the relative sizes and locations of the pork cuts used.

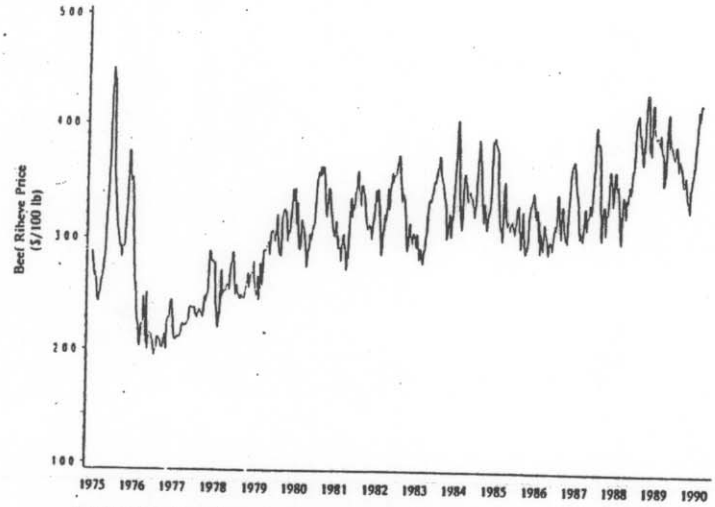

Figure 3. Plot of beef ribeye price, January 1975 to January 1990 (weekly).

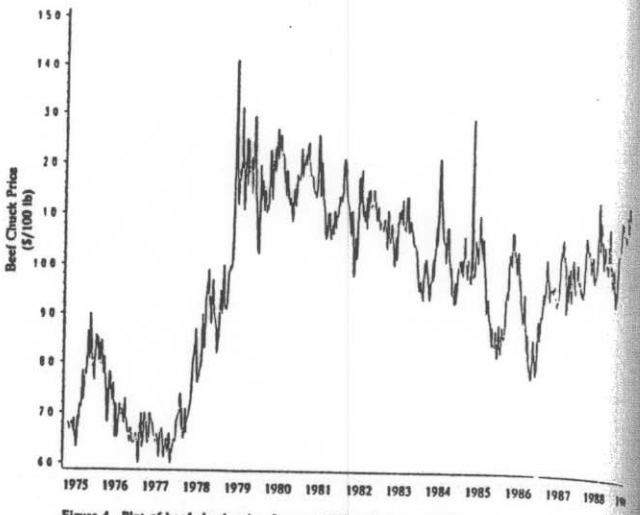

Figure 4. Plot of beef chuck price, January 1975 to January 1990 (weekly).

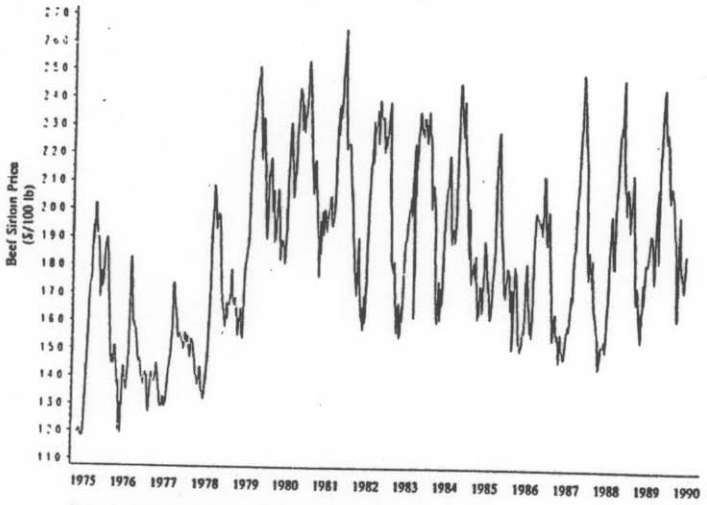

Figure 5. Plot of beef sirloin price, January 1975 to January 1990 (weekly).

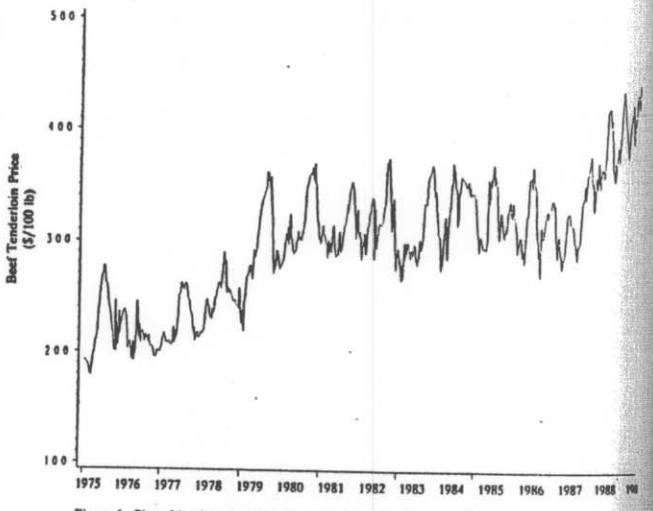

Figure 6. Plot of beef tenderloin price, January 1975 to January 1990 (weekly).

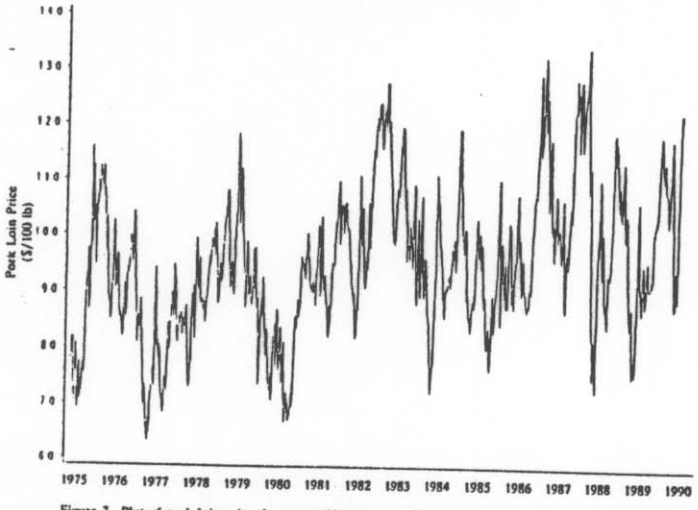

Figure 7. Plot of pork loin price, January 1975 to January 1990 (weekly).

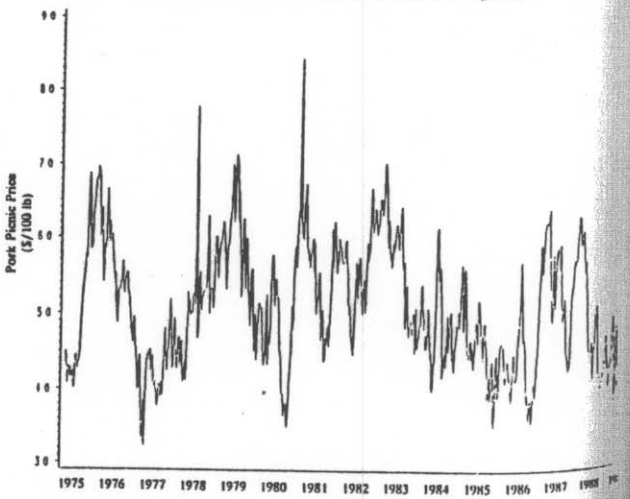

Figure 8. Plot of pork picnic price, from January 1975 to January 1990 (weekly).

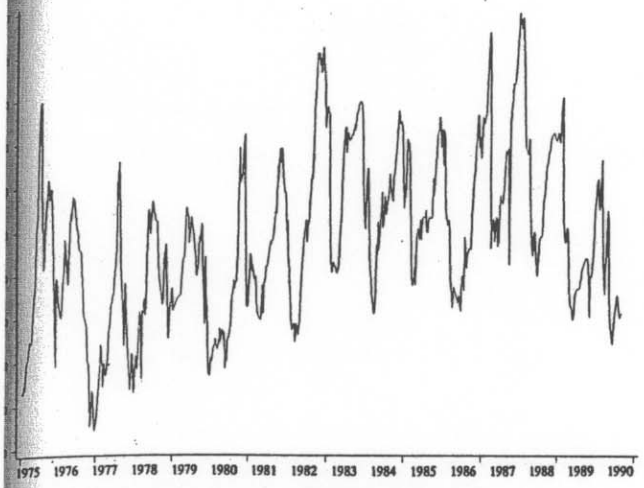

Figure 9. Plot of pork spare ribs price, January 1975 to January 1990 (weekly).

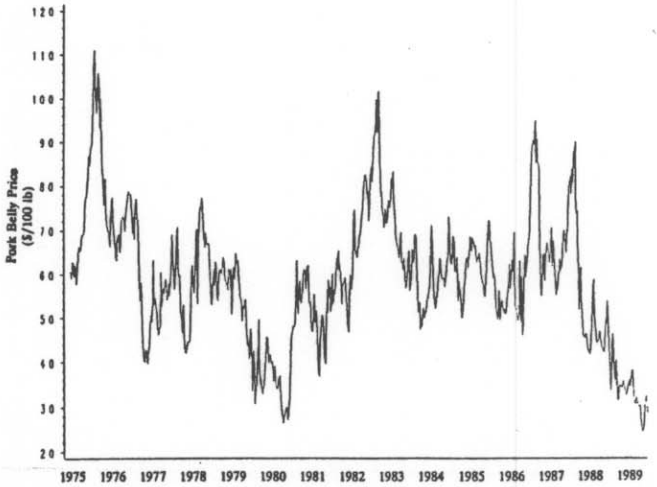

Figure 10. Plot of pork belly price, January 1975 to January 1990 (weekly).

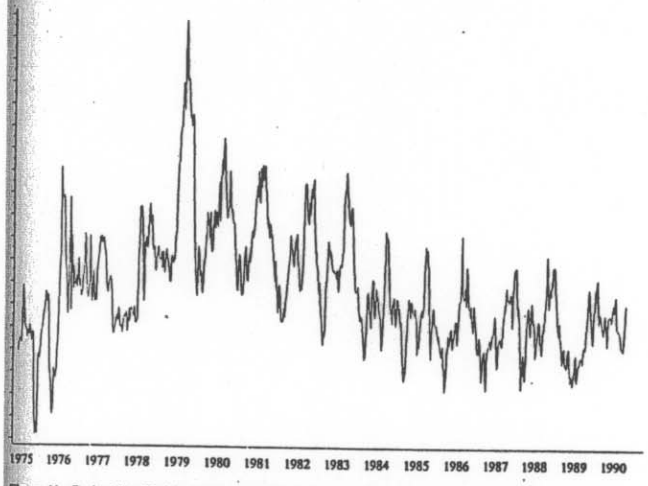

Figure 11. Ratio of beef brisket price to beef ribeye price, January 1975 to January 1989 (weekly).

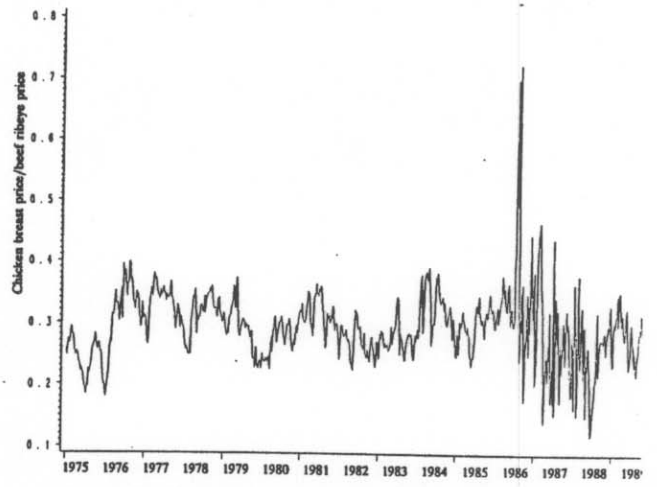

Figure 12. Ratio of chicken breast price to beef ribeye price, January 1975 to January 1989 (weekly

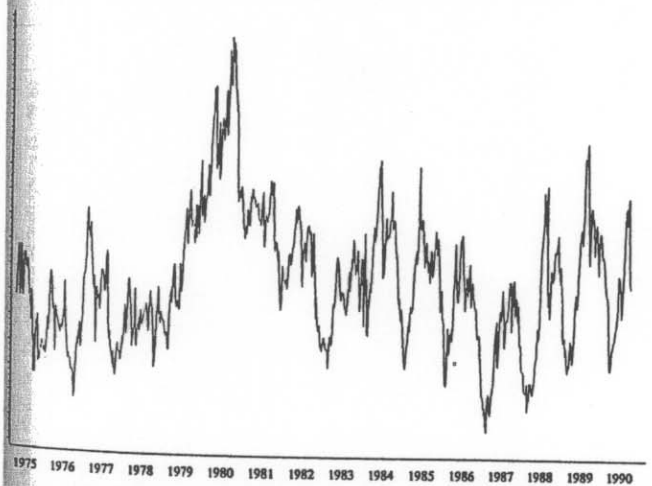

Figure 13. Ratio of beef bottom round price to pork loin price, January 1975 to January 1989 (weekly).

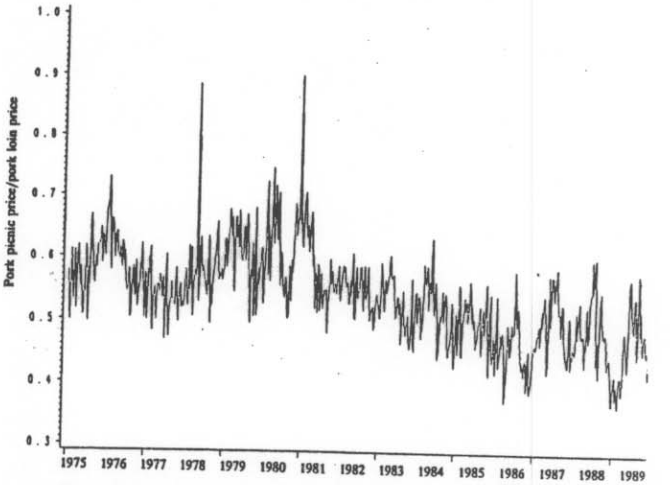

Figure 14. Ratio of pork picnic price to pork loin price, January 1975 to January 1989 (weekly).

equation basis if Slutsky symmetry is not imposed. The LA/AIDS is estimated in share-dependant form, which is desirable, given that it is unknown whether quantities adjust to reflect price changes or prices adjust to reflect the quantity supplied.

Table 1 shows the estimated elasticities from this model. In all cases, the R^2s were high and the t statistics on the own-price terms were significant at the 1 percent level.[3] Because wholesale data were used, none of the theoretical restrictions were imposed. The elasticities are consistent with *a priori* expectations. All the own-price elasticities are negative, whereas most of the compensated cross-price elasticities are positive.[4]

The magnitude of own-price elasticities for beef seems to be inversely related to quality; i.e., ribeye, tenderloin, and sirloin have elasticities of -0.07, -0.36, and -0.15, respectively, whereas the equivalent figures for ground beef, brisket, and bottom round are -0.45, -0.78, and -0.55, respectively. Most of the beef cuts are net substitutes, which is true even though the quantities of the cuts produced were perfectly correlated. As mentioned, the AIDS model uses shares as the dependent variable. Consumers can adjust the shares by changing the quantity demanded or by changing the price at which the market will clear. Consequently, the cross-price elasticities can be obtained within a particular meat subsystem, even though quantities are perfectly correlated.

The own-price elasticities for pork, ranging from -0.5 for loins to -0.8 for picnic (shoulder) hams, are much more homogeneous than are those for beef. All but five of the off-diagonal terms in the pork subsystem are positive. As with beef, the cross-price terms tend to be one order of magnitude smaller than are the own-price terms.

The chicken elasticities are very appealing. None of the cross-price terms are negative, and the own-price terms are almost identical. The magnitude of the cross-price terms is surprisingly similar in both equations.

Most of the expenditure elasticities are close to one, which may reflect the reticence of consumers (retailers) to adjust purchases within such a short time period. The magnitude of these expenditure elasticities are almost directly proportional to product price, again confirming the reasonableness of the results.

Based on these results, it can be concluded that the more expensive cuts tend to be luxury products, that the own-price elasticity for chicken is about -0.8 and that for pork is between -0.6 and -0.7, and that the own-price elasticity for beef depends on the quality of the cut.

Seasonality in Beef Demand

To estimate seasonal shifts in beef demand, a matrix of dummy variables is simply appended to the set of explanatory variables. Because the AIDS model has an intercept, one dummy less than the number of seasonal observations is used. This omitted dummy then becomes the base with which to compare the other seasonal adjustments. June was chosen as the base month, and 11 calendar month dummies were estimated.

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[3]To avoid the problems inherent in four-day work weeks, the data was aggregated to calendar months by using SAS's calendar functions.

[4]The inverse of this matrix--the flexibilities--is available from the authors on request.

Table 1. Hicksian elasticities for meat cuts demand system ($/100 lb)

	90% Ground beef	50% Ground beef	Beef ribeye	Beef brisket	Beef chuck	Beef top round	Beef bottom round	Beef sirloin	Beef tender-loin	Pork loin	Pork picnic	Pork Boston butt	Pork spare ribs	Pork ham	Pork belly	50% Ground pork	80% Ground pork	Chicken breast	Chicken leg	Expen-diture
Beef																				
90% Ground	-0.19	0.24	0.20	0.04	-0.03	0.03	-0.12	0.03	-0.04	0.07	0.16	0.01	0.02	0.04	0.02	-0.01	-0.08	0.04	0.04	0.68
50% Ground	-0.05	-0.45	0.07	0.03	0.11	0.01	-0.07	0.07	0.06	0.06	0.11	0.00	0.03	0.05	0.03	0.00	-0.01	0.02	0.03	0.84
Ribeye	0.06	-0.03	-0.07	0.02	0.01	-0.01	-0.13	-0.06	-0.02	0.07	0.00	0.01	0.01	0.04	0.00	-0.01	0.03	0.01	0.00	1.10
Brisket	0.13	0.05	0.11	-0.78	0.01	0.03	0.04	0.07	0.10	0.07	0.01	0.04	0.02	0.05	0.03	0.02	0.02	0.01	0.01	1.01
Chuck	0.07	-0.01	0.01	-0.01	-0.17	0.00	-0.01	-0.01	0.00	0.07	-0.01	0.02	0.02	0.04	0.00	0.00	0.02	0.00	0.00	1.08
Top round	0.11	0.04	0.08	0.00	0.07	-0.61	0.01	0.05	0.08	0.07	0.00	0.03	0.02	0.05	0.02	0.02	0.02	0.01	0.00	1.03
Bottom round	0.11	0.03	0.07	0.00	0.06	0.02	-0.55	0.03	0.06	0.07	-0.01	0.03	0.02	0.04	0.02	0.01	0.02	0.00	0.00	1.05
Sirloin	0.08	0.01	0.03	-0.02	0.01	0.02	-0.03	-0.36	0.04	0.05	-0.02	0.04	0.02	0.04	0.01	0.00	0.04	0.00	0.00	1.09
Tenderloin	0.05	-0.01	0.01	-0.01	0.02	0.00	-0.12	-0.02	-0.15	0.04	0.00	0.05	0.03	0.04	0.00	-0.01	0.03	0.00	-0.01	1.07
Pork																				
Loin	0.12	0.05	0.06	0.00	0.04	0.02	0.24	0.06	0.08	-0.48	-0.05	-0.02	-0.01	-0.04	0.03	0.04	0.00	0.00	0.00	1.03
Picnic	0.14	0.06	0.12	0.01	0.10	0.03	0.08	0.08	0.10	0.05	-0.79	0.03	0.02	0.04	0.03	0.03	0.01	0.01	0.01	1.00
Boston butt	0.13	0.05	0.09	0.00	0.08	0.03	0.14	0.07	0.09	0.00	-0.02	-0.63	0.01	0.01	0.03	0.03	0.01	0.00	0.00	1.01
Spare ribs	0.14	0.06	0.10	0.00	0.09	0.04	0.10	0.07	0.09	0.04	-0.01	0.02	-0.73	0.03	0.03	0.03	0.01	0.01	0.00	1.00
Ham	0.12	0.04	0.08	0.02	0.06	0.02	0.17	0.08	0.08	0.01	-0.05	-0.02	0.00	-0.53	0.02	0.04	0.00	-0.01	0.01	1.04
Belly	0.09	0.06	0.10	0.00	0.10	0.01	0.14	0.07	0.08	0.03	0.00	0.02	0.00	0.01	-0.67	0.01	0.04	0.01	0.00	1.00
50% Ground	0.09	0.07	0.11	0.00	0.13	0.02	0.09	0.08	0.11	0.01	0.01	0.03	-0.01	0.04	0.03	-0.72	0.01	0.01	0.00	1.02
80% Ground	0.14	0.06	0.11	0.01	0.09	0.03	0.09	0.08	0.10	0.04	0.00	0.02	0.01	0.03	0.03	0.02	-0.75	0.01	0.00	1.00
Chicken																				
Breast	0.15	0.05	0.12	0.01	0.10	0.01	0.06	0.10	0.10	0.06	0.00	0.06	0.00	0.06	0.03	0.03	0.01	-0.80	0.00	0.94
Leg	0.14	0.06	0.12	0.01	0.10	0.02	0.06	0.09	0.11	0.06	0.00	0.06	0.01	0.06	0.03	0.02	0.02	0.00	-0.83	0.97

It is important to note that the monthly shifts in the demand curve for particular cuts need not be related to monthly shifts in the prices for those cuts. If the price of each primal was simply regressed against the matrix of dummies, the results would replicate those already available in *Meat Price Relationships*. However, by adding these dummies onto a well-behaved demand equation, the possible impact of movements in the prices of substitute goods, the supply of the cut in question, and the import levels are separated out. Suppose, for example, that the United States imported large quantities of manufacturing beef in the fall. This imported beef would tend to drive ground beef prices down but would not be indicative of any negative shift in demand. In fact, it is possible that the ground beef was imported in anticipation of a positive shift in demand. The seasonal shifts in prices and demand are both interesting in their own right. However, as mentioned, there exists an excellent commercial source for predicting seasonal price changes. Thus, the remainder of this work will concentrate on reporting the monthly demand shifts.

Seasonal Results

Figures 15 through 33 present the seasonal shifts in the shares. *Ceteris paribus* ground beef share is lower in June than during any other month. The share for ground beef reaches a maximum in early winter. The shares for all the other beef cuts have an opposite pattern, being lowest in the fall and winter and greatest in the summer months. Pork expenditure shares tend to be greatest in the fall, with the exception of pork bellies and ground pork, which have less seasonal patterns. The chicken share is greatest in the first six months of the year and lowest in the second.

One possible explanation for the seasonal changes in beef share may be a preference for beef over pork and chicken during the barbecue season. Most ground beef is consumed in fast-food restaurants, which may suffer a loss of business when people eat out in summer. These results indicate that the ground beef share is very different from other beef cut shares. The implication is that ground beef should be separated from beef in demand analysis.

The strength of the pork cuts share in the fall is surprising. Our *a priori* expectations would have predicted peak demand for ham at Easter and a peak for ribs in summer. One possible explanation is that supply cutbacks in the fall cause greater than proportional price increases (the demand curve is inelastic), thereby increasing pork expenditures and ultimately the pork share in meat expenditures. The seasonal pattern in the chicken share is also interesting, particularly for the June to July period. An abrupt midsummer change was not expected.

It must be remembered that when the share of one commodity or meat increases, the share of at least one other commodity must fall because the sum of the shares must sum to one. There are four distinct seasonal patterns for meats. Ground beef behaves in a dissimilar manner to other beef. These seasonal patterns are more consistent for all cuts of pork and chicken because all cuts seem to have similar patterns. The reasons for these interesting patterns deserves further analysis.

Summary and Conclusions

This paper argues that meats (i.e., beef, pork, and poultry) should not be treated as homogeneous commodities in estimation and introduces a data set that provides the prices

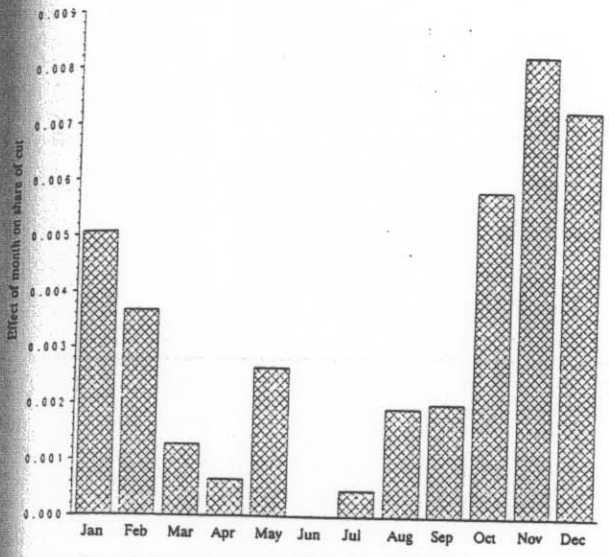

Figure 15. Seasonal effects on the 90% ground beef expenditure share.

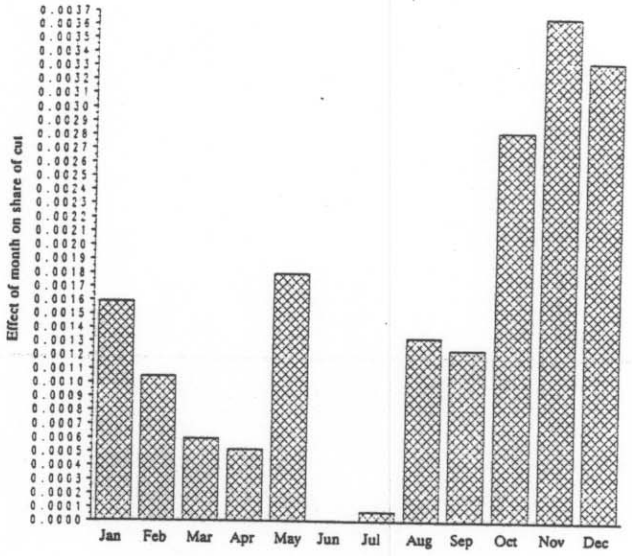

Figure 16. Seasonal effects on the 50% ground beef expenditure share.

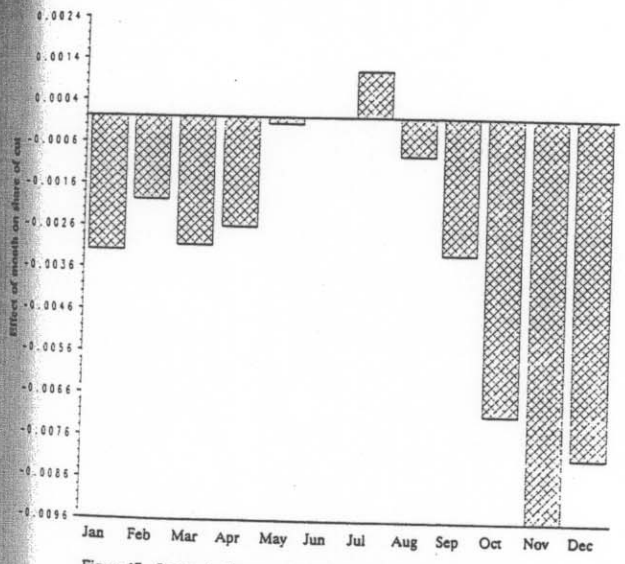

Figure 17. Seasonal effects on the beef ribeye expenditure share.

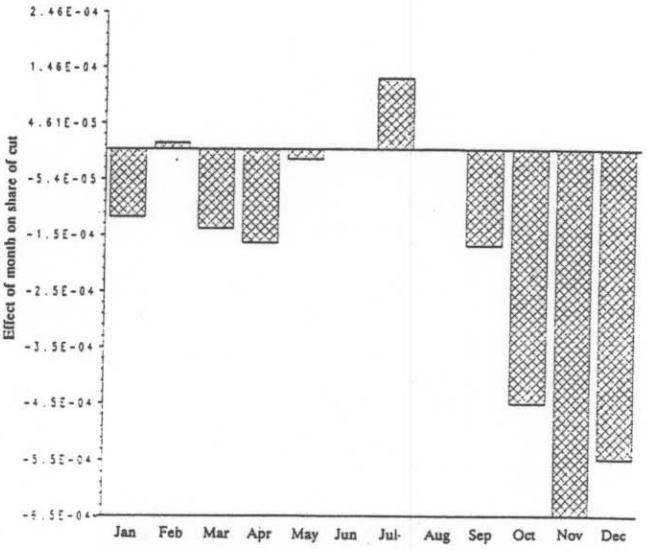

Figure 18. Seasonal effects on the beef brisket expenditure share.

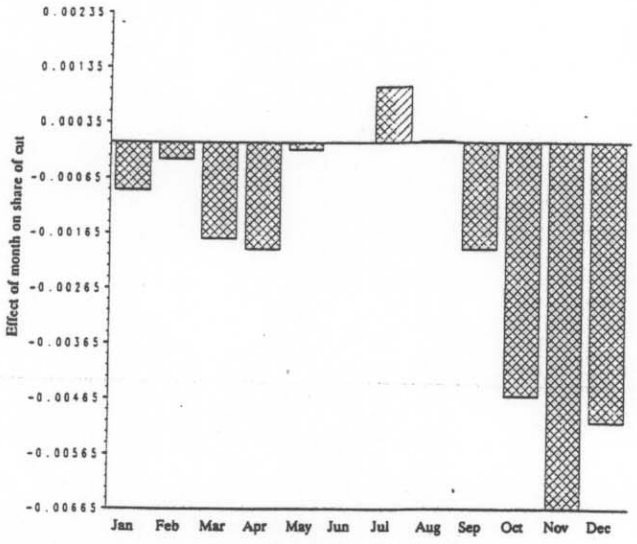

Figure 19. Seasonal effects on the beef chuck expenditure share.

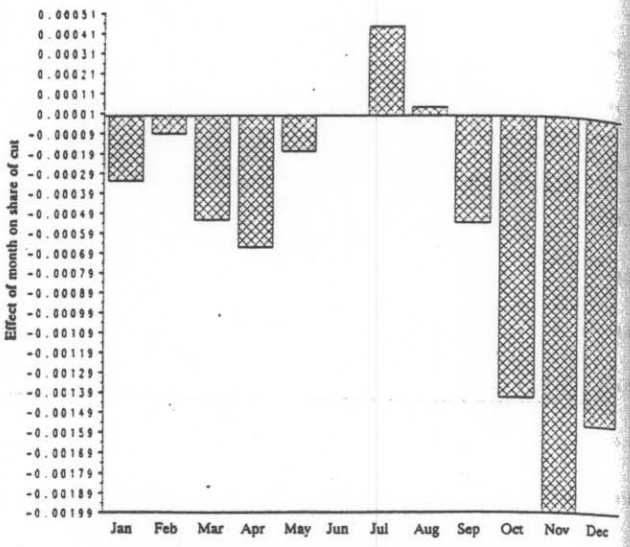

Figure 20. Seasonal effects on the beef top round expenditure share.

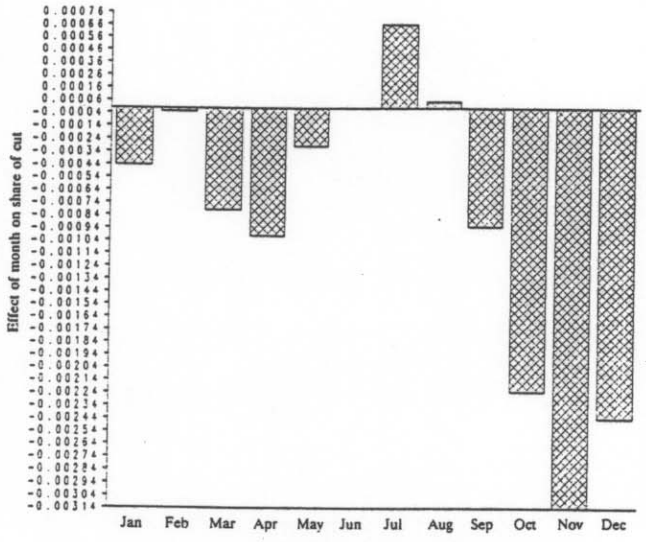

Figure 21. Seasonal effects on the beef bottom round expenditure share.

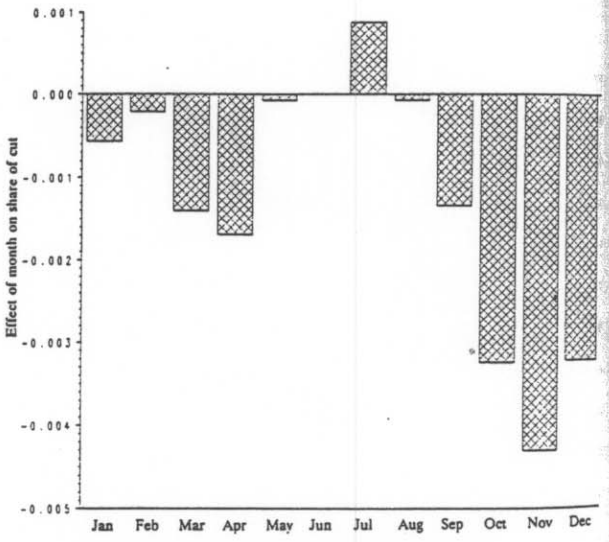

Figure 22. Seasonal effects on the beef sirloin expenditure share.

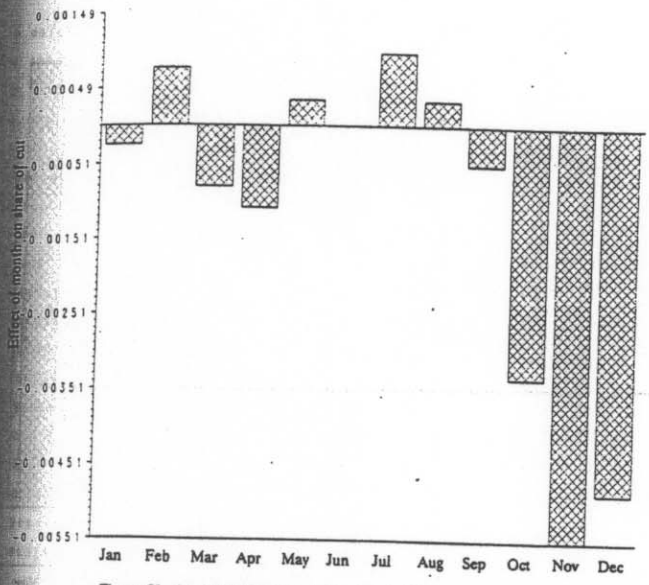

Figure 23.. Seasonal effects on the beef tenderloin expenditure share.

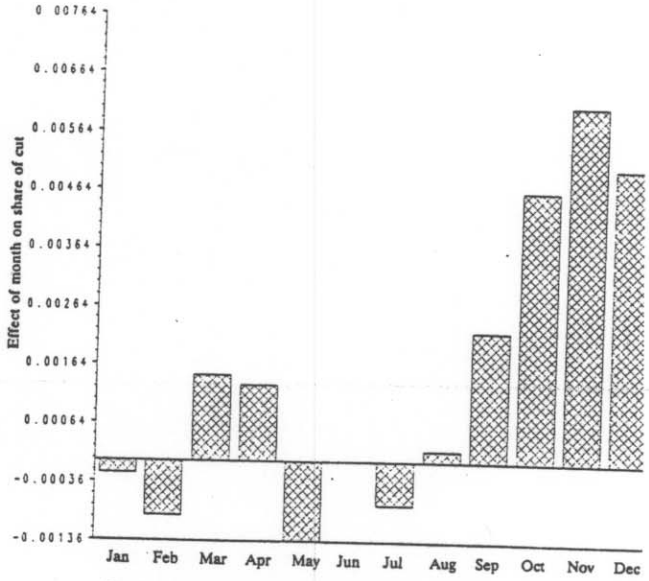

Figure 24. Seasonal effects on the pork loin expenditure share.

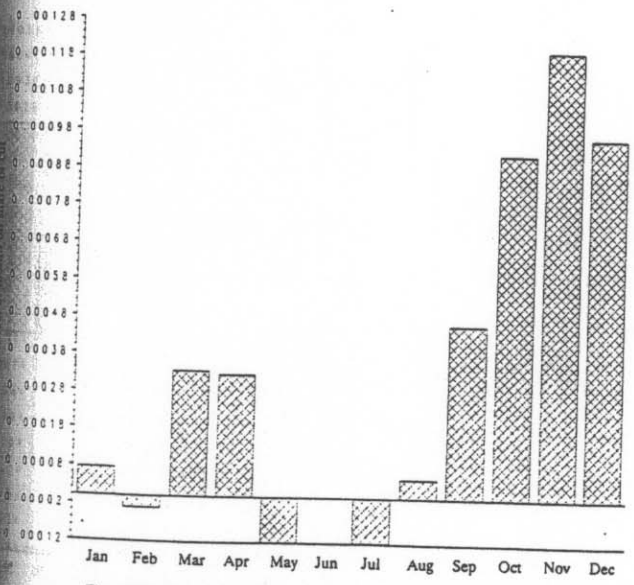

Figure 25. Seasonal effects on the pork picnic expenditure share.

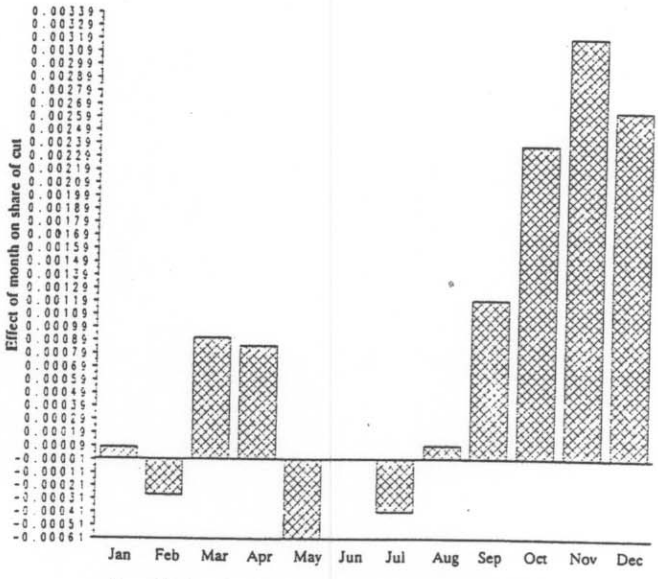

Figure 26. Seasonal effects on the pork Boston butt expenditure share.

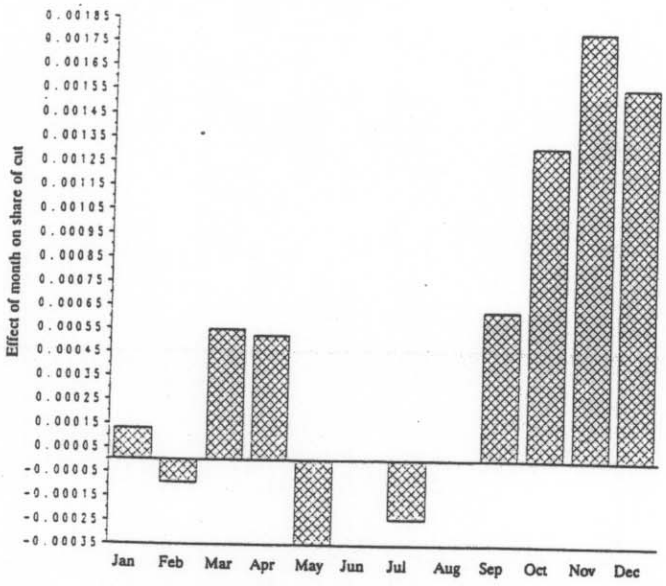

Figure 27. Seasonal effects on the pork spare rib expenditure share.

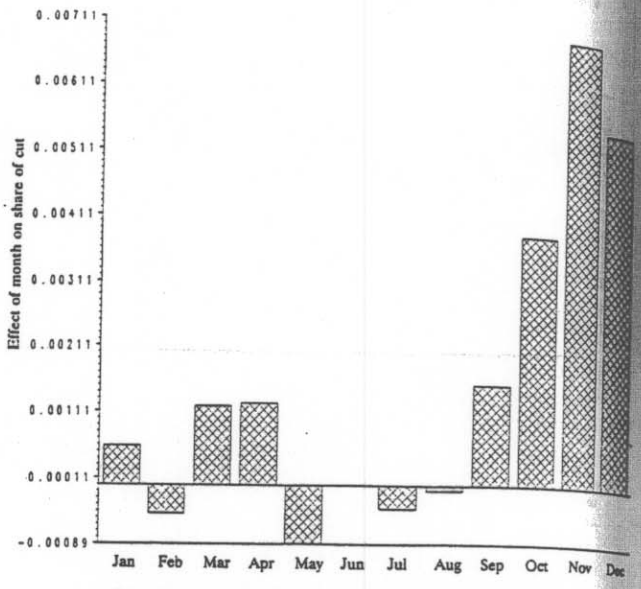

Figure 28. Seasonal effects on the pork ham expenditure share.

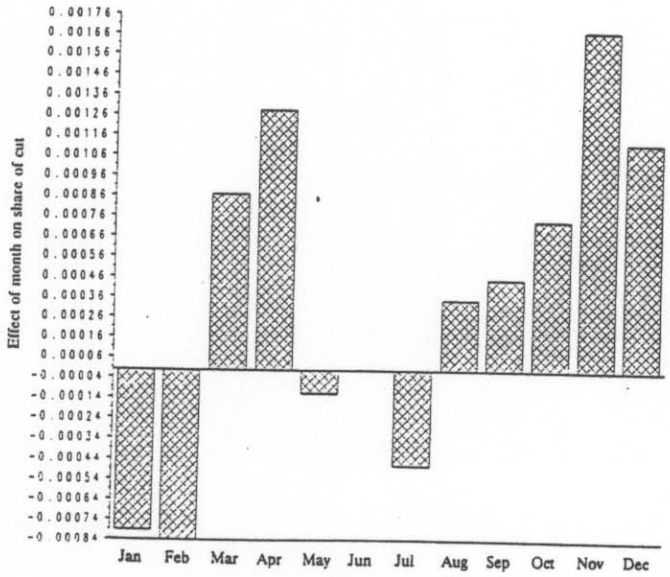

Figure 29. Seasonal effects on the pork belly expenditure share.

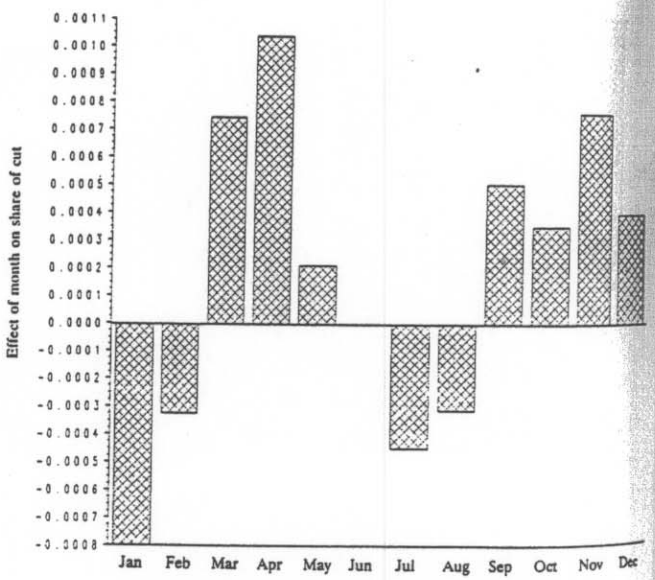

Figure 30. Seasonal effects on the 50% ground pork expenditure share.

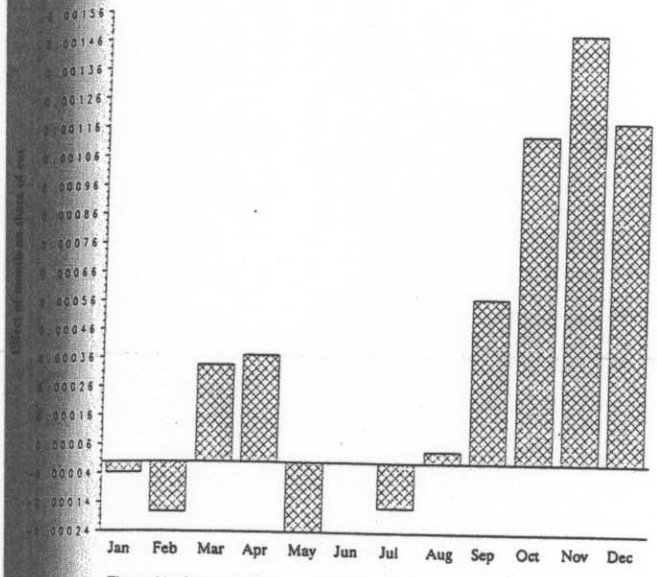

Figure 31. Seasonal effects on the 80% ground pork expenditure share.

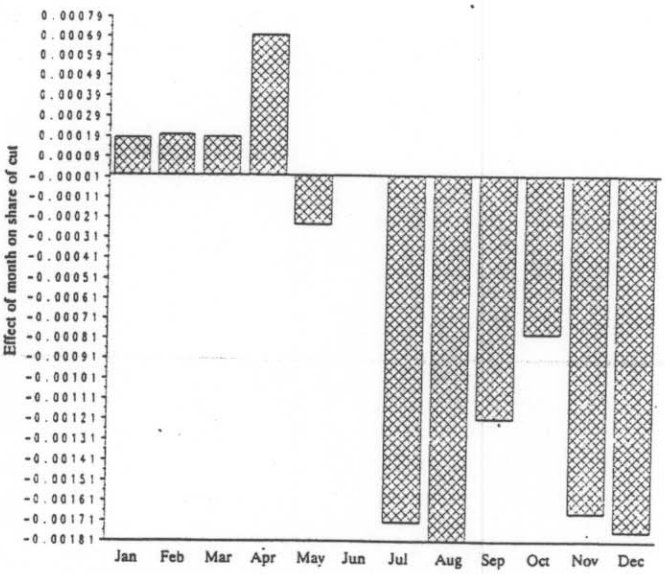

Figure 32. Seasonal effects on the chicken breast expenditure share.

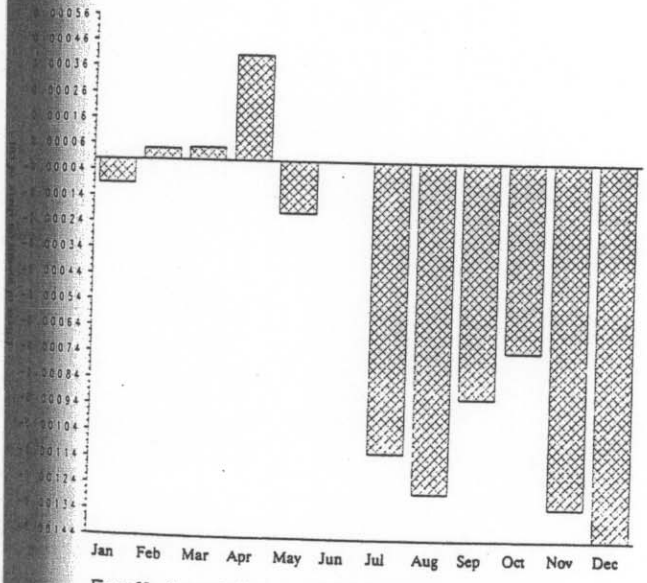

Figure 33. Seasonal effects on the chicken leg expenditure share.

and quantities of individual meat cuts on a weekly basis. These data show that the prices of the more expensive meat cuts have risen at a faster rate than have those of other cuts and that seasonal changes tend to dominate year-to-year price changes in terms of magnitude.

The data were used to estimate an Almost Ideal Demand System, which is reported in this paper. These elasticities indicate that the own-price elasticity of beef demand varies with the price of the beef cut (the demand for more expensive cuts being less sensitive to price). The own-price elasticities for the pork and poultry cuts also exhibit a price dependence but are much more tightly bunched. The expenditure elasticities are all close to one and are directly proportional to the price of the cut.

The dummy variables used to estimate the system are also discussed. These variables indicate that the shares of more expensive beef cuts tend to be greatest in mid-summer, whereas those for pork are greatest in the fall. The chicken share is greatest in the first half of the year and lowest in the second half.

The seasonal effects for pork and poultry are surprising and may indicate that supply effects, or U.S. exports and imports, are important determinants in the system. These trade effects are of relevance because the model is estimated at the wholesale level as opposed to the retail level for most previous studies. Consequently, large export sales (i.e., to Japan for their gift-giving season) can have an impact on the model, just as they have an impact on wholesale prices in reality.

Much work remains to be done with the data. The number of observations allows for the estimation of the more parameter-intensive dynamic models. Also of great interest is how U.S. imports and exports of meat products influence prices and consumption within the United States.

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