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The Demand for Beef Products: Cross-Section Estimation of Demographic and Economic Effects

Dale Heien and Greg Pompelli

This paper presents estimates of the economic and demographic effects on the demand for steak, roast, and ground beef. Using an almost ideal demand system, the results indicate that demand is inelastic for steak and ground beef, elastic for roast, cross-price effects are significant, and all goods are Hicks-Allen substitutes. The impact of certain demographic effects, such as household size, region, tenancy, and ethnic origin, was generally quite significant. Other demographic variables, such as employment status, shopper, and occupation, were generally not significant.

Key words: beef products, demand analysis, demographic effects, price elasticities.

The composition and quantity of red meat consumed in the United States has changed considerably in the past two decades. During this period beef producers and marketers have looked for explanations which offer insights about future changes in consumer demand. A recent National Cattleman's Association nineteen-city survey (*Beefweek*) of beef cut demand has indicated that the mix of beef cuts demanded continues to be a concern in the retail market. The Cattleman's survey has shown a continued decline in demand for roast cuts in relation to steak cuts and ground beef. Given the relative importance of the beef industry to the agricultural economies of many states, these concerns have not been taken lightly. On the production side, producers have the ability to alter the composition and quality of retail cuts through breeding, but a lag between the recognition of a change in demand and the production response still exists. This lag, and the expense associated with producing animals poorly suited to the needs of the market has made it all the more important to examine the demand for beef in terms of retail cuts. Unfortunately, the research to date, while useful, has left a gap in beef demand by not looking

at the area of the demand for specific cuts of beef.

In general, prior meat demand literature can be divided into two areas. The first views the changes in beef demand as a response to changes in the demographic and socioeconomic composition of the whole meat-consuming population (Blaylock and Haidacher; Blaylock and Smallwood; Capps and Havlicek). The second point of view holds that the changes in beef demand are structural (Braschler; Chavas; Leuthold and Nevagbo; Moschini and Meilke; Tomek). This paper focuses on the first approach by examining the demand for three major cuts of beef: steak, roast, and ground beef.

The changing demographic profile of the U.S. population has had dramatic impacts on the demand for food. The postwar baby boom, the gradual aging of the population, and the increase in female labor force participation are especially important.¹ The heterogeneity of demographic effects is clearly evident when analyzing cross-section data. Aggregate demographic time-series data often display smooth trends, exacerbating the collinearity problems already inherent in economic time series. This increased multicollinearity makes accurate estimation difficult. Also, for food items, the level

Dale Heien is an associate professor in the Department of Agricultural Economics, University of California, Davis. Greg Pompelli is an assistant professor in the Department of Agricultural Economics and Rural Sociology, University of Tennessee.

¹ For a more complete discussion of these factors and their significance, see Kinsey and Heien and the references cited therein.

of commodity detail available in the time-series data is often limited to farm-level raw agricultural products. This is particularly true for beef, where it is extremely difficult to construct an accurate time series on beef consumption by products.

The purpose of this analysis is to identify the major demographic factors responsible for the changing beef market shares of the three major retail cuts. In addition to quantifying the impacts of household characteristics, this study will estimate the price and expenditure elasticities of demand for each of the three beef cuts. In doing so, this paper will highlight relations that can be used to help the beef industry meet the changing needs of the market as the demographic features of the market change.

Model Specification

The demand model selected as the framework for this study is the Almost Ideal Demand System (AIDS) (Deaton and Muellbauer). The AIDS model has several advantages. It is easy to estimate, does not impose any a priori restrictions on the degree of substitution among commodities, and is compatible with household budget behavior by allowing for nonlinear Engel curves. Also, restrictions of economic theory are readily imposed. The AIDS demand model can be derived from the Gorman polar form cost (expenditure) function,

$$(1) \quad \ln m(U, p) = \ln P + U\beta(p),$$

where

$$(2) \quad \ln P = \alpha_0 + \sum_{i=1}^n \alpha_i \ln p_i + \frac{1}{2} \sum_{i=1}^n \sum_{j=1}^n \gamma_{ij} \ln p_i \ln p_j,$$

$$(3) \quad \beta(p) = \beta_0 \prod_{i=1}^n p_i^{\beta_i},$$

and m is the minimum expenditure needed to achieve utility level U under prices p . The demand equations associated with this system are

$$(4) \quad w_i = \alpha_i + \sum_{j=1}^n \gamma_{ij} \ln p_j + \beta_i \ln(m/P) \quad i = 1, \dots, n,$$

where $w_i = p_i q_i / m$ is the budget share and q_i is the quantity demanded. The adding-up restriction is met if $\sum_{i=1}^n \alpha_i = 1$, $\sum_{i=1}^n \gamma_{ij} = 0$, and $\sum_{i=1}^n \beta_i =$

0. By imposing $\sum_{j=1}^n \gamma_{ij} = 0$ ($i = 1, \dots, n$) the homogeneity condition is met, and requiring $\gamma_{ij} = \gamma_{ji}$ for all i, j ($i \neq j$) insures symmetry. Demographic effects are incorporated in the model by allowing the intercept in (4) to be a function of demographic variables, or

$$(5) \quad \alpha_i = \rho_{i0} + \sum_{j=1}^S \rho_{ij} d_j \quad i = 1, \dots, n,$$

where d_j is the j^{th} demographic variable of which there are S . The price and income elasticities for the AIDS model are given by

$$(6) \quad e_{ij}^* = w_i^{-1} \left[\gamma_{ij} - \beta_i \left(\alpha_j + \sum_{r=1}^n \gamma_{rj} \ln p_r \right) \right] - \delta_{ij} \quad \text{and}$$

$$(7) \quad e_i = 1 + \beta_i / w_i,$$

where δ_{ij} is the Kronecker delta. It is clear that the demographic variables, through their influences on the budget shares (the w_i 's), affect the magnitude, but not the sign, of these elasticities. For instance, the classification of goods as to luxuries or necessities is not affected by demographic variables. However, they do affect whether or not demand is elastic as can be seen from (6). Under this specification the

adding-up criterion now requires that $\sum_{i=1}^n \rho_{i0} =$

1 and $\sum_{i=1}^n \rho_{ij} = 0$ ($j = 1, \dots, S$).

The specification given here implies that the demand for these three beef products is separable with respect to the rest of the items in the consumer's budget. Hence, the AIDS given above pertains to the second stage of a two-stage budgeting procedure. This specification also means that the marginal rate of substitution (MRS) between, say, roast and steak, is independent of the amount consumed of other foods, say, pork or chicken. This does not appear nearly as restrictive as assuming the MRS between beef and pork is independent of chick-

en. In this conceptualization, consumers decide how much to spend on beef and then allocate this total among steak, roast, and ground beef. The first-stage decision is based on price indexes for beef and other food and nonfood groups. The first-stage demand relation is not estimated in this study. Hence, we are concerned only with the demographic and economic effects within the second-stage allocation.

Data and Estimation Considerations

The data used in this study are from the USDA spring 1977 Household Food Consumption Survey (HFCS).² The survey contains data from 3,196 households across the nation. In estimating a complete system of demand questions such as the AIDS, it is known that the variance-covariance matrix for the complete n -good system is singular. The usual procedure is to drop one of the equations, rendering the remaining $(n - 1) \times (n - 1)$ variance-covariance matrix nonsingular. If maximum likelihood estimation is used, the resulting estimates will be invariant to which equation is dropped. Because Iterative Zellner (IZEF) for complete demand systems is equivalent to maximum likelihood, estimates made by IZEF will also be invariant. A problem arises in considering how to treat households who do not consume any of the three beef products. For this case the expenditure on each individual item is zero as well as total group expenditure. In this case the budget share is not defined. We chose to delete these observations on the basis that if the interval of observation were longer (it is a one-week period for the HFCS), these households would be observed consuming some beef product.³ The alternative is to employ some sample-selection-bias correction procedure. Such procedures rely on the notion that consumers do not consume because market prices exceed reservation prices for these items. We find the former paradigm more ap-

pealing. Hence, the sample was restricted to the 2,870 households who consumed at least one of the three items. However, among the included households a further problem arises because some of the budget shares are zero. Although decisions to consume or not are often treated as dichotomous logit models, we follow the approach of Wales and Woodland and assume that zero quantity consumed is consistent with a continuous demand curve. Estimation by IZEF when the joint error distribution is assumed to be multivariate normal can lead to budget shares which exceed unity or are less than zero. In order to correct for this problem, Woodland introduced the Dirichlet, which is bounded by the unit simplex, as the budget share distribution. In Monte Carlo studies, Woodland found that for the case of relatively few zero budget shares, the estimates made under the Dirichlet assumption showed little difference from those made under the multivariate normal one. Because over 80% of the shares here are nonzero, we felt comfortable with the multivariate normal assumption.

Another problem relates to the data on prices. In a complete system it is necessary to have data on prices on all goods in the model for all households regardless of whether or not a particular household consumes that good. For households not consuming a particular good, no data on the price they faced for that good exists. The problem was remedied by estimating the missing price data using regression techniques. Hence, three regressions were run, one for each of the three prices in the model. Observations for those households consuming the items were regressed on income and region in order to estimate the missing prices. Less than 20% of the 8,610 observations on prices were estimated in this manner. The statistical properties of this approach are discussed in Dagenais and in Gourieroux and Monfort.

In order to maintain the linearity of the estimation technique the authors employed the linear approximation for P ,

$$(8) \quad \pi = \sum_{i=1}^n \bar{w}_i \ln p_i,$$

as suggested by Deaton and Muellbauer. The restrictions implied by economic theory were not tested but were imposed on the data. The appropriate statistic for this test has been ques-

² The sample size was restricted to spring because of cost limitations involved in adding dummy variables for seasons as well as dealing with 9,000 more observations. Given the cross-equation restrictions and the price estimation technique described below, these cost considerations are nontrivial. Seasonal effects in the demand for beef products were generally not significant in the Haidacher et al. study.

³ For a similar concept in dichotomous choice models, see Anas and Moses.

tioned by Laitinen. Also, the meaning of the test results is often obscured by other considerations. For example, if the test rejects the restrictions, it may be because consumers do not maximize utility because the functional form is misspecified or because the paradigm is too narrow (e.g., labor supply should be endogenous). Aggregation questions can cloud the test results in a similar manner.

Empirical Results

The appendix presents the parameter estimates of the AIDS for steak, roast, and ground beef. These three goods compose over 95% of consumer expenditures for beef. The price and expenditure coefficients are highly significant.

The Marshallian price and expenditure elasticities for this demand system are given in table 1. It should be borne in mind that these are only partial price elasticities, since we are dealing with a separable system of goods. As is true for most separable systems which have been used in empirical work, the total expenditure on any group is a function of a price index for that group and price indexes for all other groups.⁴ In this case, total expenditure on beef will depend in part on a price index composed of steak, roast, and ground beef prices. Hence, the elasticities computed here are partial in the sense that the effect of any of the three prices on total beef expenditure is not considered. However, using extraneous information from other studies it is possible to make some inference concerning the total elasticities for these three products. First consider the demand for the i th beef product,

$$(9) \quad q_i = p_i^{-1} m \left[\alpha_i + \sum_{j=1}^n \gamma_j \ln p_j + \beta_i \ln(m/p) \right],$$

where the first-stage demand relation for m is given by

$$(10) \quad m = m(X_1, \dots, X_G, y),$$

where the X_j 's ($j = 1, \dots, G$) are the price

indices for the various groups and y is total expenditure or income. The total own-price

elasticity $e_{ii} = \frac{\partial q_i}{\partial p_i} \cdot \frac{p_i}{q_i}$, is given by

$$(11) \quad e_{ii} = e_{ii}^* + e_{q_i-m} \cdot e_{m-x} \cdot e_{x-p_i},$$

where e_{ii}^* is given by (6), and

$$(12) \quad e_{q_i-m} = \frac{\partial q_i}{\partial m} \cdot \frac{m}{q_i}$$

$$(13) \quad e_{m-x} = \frac{\partial m}{\partial X} \cdot \frac{X}{m}$$

(for X_j which contains p_i) and

$$(14) \quad e_{x-p_i} = \frac{\partial X}{\partial p_i} \cdot \frac{p_i}{X}.$$

Studies of beef demand by Brandow and by Heien have found price elasticities close to unity. Other studies generally have found values between $-.5$ and -1.0 , most of which are not significantly different from minus one, by generally accepted standards. Defining the quantity of beef consumed, Q , as

$$(15) \quad Q = m/\pi,$$

where π is given by (8), then $e_{Q-\pi} = e_{m-\pi} - 1.0$, where $\pi = X$ (for the beef group). Then, from (8), $e_{x-p_i} = w_i$, $e_{m-\pi} = e_{Q-\pi} + 1.0$, and e_{q_i-m} is given in table 1. Given the above cited values for $e_{Q-\pi}$, it is highly unlikely that the total elasticities will differ greatly from the partial elasticities. As $e_{Q-\pi}$ approaches -1.0 , the total elasticity approaches the partial elasticity. The partial price elasticities are presented in table 1. It is interesting to note that four of the six cross-price effects are negative in table 1, while table 2 shows all goods to be Hicks-Allen substitutes (i.e., the Slutsky cross-elasticities are all positive). Hence, the income effect outweighs the substitution effect in four of six cases.

Comparison of the above results to those found by other authors is difficult, and typically inconclusive since models, data, and time periods used are not similar. Nonetheless, the comparisons among studies may offer some useful insights. For example, using data from the 1972-74 Bureau of Labor Statistics Consumer Expenditure Dairy Survey, Capps and Havlicek estimated the demand for meat, poultry, and seafood with the S -branch system. Their price elasticity results are presented

⁴ The technical requirement is that the group utility functions be homothetic or that the indirect utility function have the generalized Gorman polar form. Most empirical studies using separable systems have used a utility function which fits the latter definition.

Table 1. Marshallian Partial Price and Expenditure Elasticities for Beef Cuts Model

	Steak	Roast	Ground Beef	Expenditure
Steak	-.73	-.17	-.24	1.14
Roast	-.39	-1.11	.13	1.37
Ground beef	-.05	.21	-.85	.69

Note: Elasticities are evaluated at the sample means.

in table 3. As expected, their estimates of the calculated price elasticities differ from ours. Aside from the time period examined, one reason for these differences is that *S*-branch system cross-price elasticities are characteristically much smaller than the own-price elasticities. The AIDS system does not have this tendency. Thus, our cross-price elasticities indicate relatively greater influences than those found by Capps and Havlicek. At the same time, our own-price elasticities are not as dominant as those found by Capps and Havlicek.

Although many of the demographic variables were significant, their impacts were typically quite small. The results indicate that household size, urbanization, and ethnic background are the only factors which significantly influence demand across all three beef categories. With the exception of household shoppers, the other demographic variables are shown to have a significant influence on at least one type of beef but not all the beef cuts. This finding confirms the importance of viewing the demand for beef by cuts. As others have found (Blaylock and Smallwood; Capps and Havlicek) disaggregating beef demand offers many more insights than are found by looking only at beef in general.

Black and Hispanic households have a significant influence in the demand for each beef product examined. A similar result was found by Blaylock and Smallwood. Increased proportions of black or Hispanic households will increase the demand for steak and decrease the demand for ground beef; but roast demand decreases with increased proportions of Hispanic households, while it increases when the proportion of black households increases.

The regional and location influences on demand for beef products are mixed and difficult to interpret, especially if viewed as differences in tastes across regions of the United States. Nonetheless, the results indicate significant rural and northern regional influences, which may

Table 2. Hicks-Allen Partial Elasticities for Beef Cuts Model

	Steak	Roast	Ground Beef
Steak	-.30	.07	.23
Roast	.12	-.82	.69
Ground beef	.21	.36	-.57

Note: Elasticities are evaluated at the sample means.

be due to more traditional beef-eating habits in those areas. The lack of influence in the South and suburban areas may be caused by the migration to those areas by households from other regions. Thus, the tastes of the South and suburbs most likely represent a mixture of preferences from all regions.

Of the household characteristics which appear to exhibit little influence on beef demand, the employment status of the female head is somewhat conspicuous for its lack of significance. However, in general, occupational and employment status of the heads of the household showed little impact in the demand for beef. The sex of the primary food shopper in the household also does not exhibit a significant influence on the demand for any cut of beef.

Summary and Conclusions

In this paper, we estimated the price and expenditure elasticities of demand for the three major cuts of beef: steak, roast, and ground beef. The Almost Ideal Demand System was used as a framework. To incorporate population demographics, the AIDS model was expanded by specifying the intercept as a linear function of demographic variables. In general, the coefficients for the price variables are highly significant. Demand is inelastic for steak and ground beef and elastic for roast. All goods are substitutes in the Hicks-Allen sense. The most

Table 3. Capps and Havlicek Price Elasticities for Beef Products

	Steak	Roast	Ground Beef	Expenditure
Steak	-1.75	0.07	0.04	1.38
Roast	0.09	-1.83	0.04	1.44
Ground beef	0.07	0.06	-1.52	1.16

Source: Capps and Havlicek. Uncompensated elasticities.

significant demographic effects come from household size, region, tenancy, and ethnic origin. Occupation, urbanization, and shopper did not strongly affect the demand for these cuts. This analysis has shown there are strong own-price and cross-price effects among beef cuts. Second, the analysis indicates that the demographic profile of the U.S. population does have a significant impact on the demand for these commodities, even within the confines of the second-stage budget allocation.

Although the study is limited somewhat by the lack of a more recent data set, the results serve to indicate several important factors which the beef industry can use as a basis for meeting the changing demand for beef in the market place. These results also serve as a reference point for future studies which analyze beef demand by product categories and use demographic information to study the differing influence of household characteristics on the demand for each cut of beef.

Our results offer a number of explanations for the lower demand for roast cuts in relation to steak and ground beef at the retail level. As shown in the text, changing household sizes and ethnic factors are important features which beef marketers may use to adjust their marketing as well as product planning and development. For example, these results may be used to focus marketing efforts for established beef cuts on market segments which have a greater interest in using those cuts. This information can also be used to develop new beef products which avoid negative features or take advantage of positive characteristics found in various markets. These changes may include innovations in packaging or other added features as well as changes in retail beef cuts. In any case, these results indicate the benefit of using more precise consumer information along with more detailed product information to assess the market opportunities for beef at the retail level.

While this study indicates the benefits of increased product specificity and detailed demographic information, further studies using the next USDA Food Consumption Survey or scanner data will provide an even richer source of information. Such data could be used to look at the impact of beef cut sizes, product quality, fat content, or even the impact of branded beef.

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Appendix

Table 1. Parameter Estimates and Associated *t*-values for AIDS Beef Products Model

Variable	Mean	Steak	Roast	Ground Beef
Intercept		.557 (12.3)	.488 (12.3)	-.045 (1.0)
Household size	3.116	-.026 (5.7)	-.019 (4.8)	.044 (10.3)
Location: Suburban ^a	.348	-.014 (0.8)	-.0014 (0.1)	.015 (0.9)
Rural	.365	-.042 (2.4)	-.023 (1.5)	.065 (3.9)
Region: Northeast ^b	.226	.047 (2.2)	-.0047 (0.3)	-.043 (2.1)
North Central	.274	-.021 (1.0)	-.0005 (0.03)	.021 (1.1)
South	.336	.0002 (0.01)	.0057 (0.3)	-.006 (0.3)
Tenancy: Owner ^c	.713	-.013 (0.8)	.043 (3.2)	-.03 (2.1)
Origin: Spanish ^d	.037	.104 (3.0)	-.06 (2.0)	-.044 (1.3)
Black	.103	.027 (1.2)	.018 (0.9)	-.045 (2.0)
Male employed	.617	.042 (1.5)	-.026 (1.0)	-.016 (0.6)
Female employed	.383	.0024 (0.2)	.0034 (0.3)	-.006 (0.5)
Male occupation: Professional ^e	.136	.01 (0.3)	.031 (1.1)	-.041 (1.3)
Managerial	.106	-.0033 (0.1)	.021 (0.7)	-.017 (0.5)
Farmer	.022	.07 (1.3)	-.035 (0.8)	-.036 (0.7)
Clerical	.049	.009 (0.2)	-.030 (0.8)	.02 (0.5)
Craftsman	.169	.009 (0.3)	.01 (0.4)	-.019 (0.6)
Operative	.071	-.017 (0.5)	.04 (1.3)	-.025 (0.7)
Service	.059	-.006 (0.2)	.008 (0.2)	-.002 (0.05)
Shopper: Female ^f	.707	.0017 (0.7)	.017 (0.7)	-.018 (0.7)
Male	.087	.02 (0.6)	.004 (0.2)	-.023 (0.7)
Female and male	.126	.007 (0.2)	.0012 (0.4)	.008 (0.3)

Appendix
Table 1. Continued

Variable	Mean	Steak	Roast	Ground Beef
Prices: Steak	116.03	.132 (12.7)	-.041 (5.0)	-.091 (11.5)
Roast	97.96	-.041 (5.0)	.114 (1.1)	.030 (3.9)
Ground beef	77.46	-.091 (11.4)	.030 (3.9)	.061 (6.4)
Expenditure		.052 (6.2)	.079 (10.7)	-.131 (16.5)
Mean budget share		.378	.211	.411
SSE		^g	254.1	306.5
SSR			14.9	51.1
\bar{R}^2		.078	.047	.135

^a Omitted location: inner city.
^b Omitted region: West.
^c Omitted tenancy: renter.
^d Omitted origin: Caucasian.
^e Omitted occupation: other.
^f Omitted shopper: female and other, male and other.
^g Steak was the deleted good.