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12. Determinants of Demand for Beef: The Impact of Fat Trimming

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12

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From 1976 to 1991 per capita beef (including veal) consumption declined from 89 to 63 lbs. (Payson 1994). This is partially attributed to consumer health concerns (Gao and Shonkwiler 1993). According to CAST (1991), consumers would purchase more beef if the fat was well trimmed for retail display. In addition, consumers will expect meat products in the 1990s to be leaner, more convenient to prepare, and perceived to be healthful. Based on these consumer views, an economic analysis on the relationship between consumer perception of fat and demand for beef is particularly timely. In the early 1980s, Tracy (1980) pointed out that knowledge about the extent to which nutritional concerns are influencing food consumption patterns has important implications for the marketing system.

In the past several decades, the relationship between undesirable nutrients such as fat and cholesterol in the American diet and public health has been well recognized. Many economists such as Brown and Schrader (1990) and Capps and Schmitz (1991) have started incorporating consumer health concerns and nutrition into food demand analysis. They all found consumer health and nutrition concerns have a significant effect on food demand. However, they only incorporated a cholesterol information index into their demand models. How consumers perceived and their concerns about undesirable nutrients such as fat and cholesterol in food were overlooked. Recently, Unnevehr and Bard (1993) reported that consumers are willing to pay more for removing fat from beef. Unfortunately, they did not investigate the impact of consumer perceptions of fat on beef demand.

This chapter focuses on the trimming of excess fat (external and internal fats are not distinct in this study) from beef by examining the relationship between consumer perceptions of fat and demand for beef using the 1987-88 Nationwide Food Consumption Survey data. Beef is postulated to be available in a variety of qualities. Consumers make decisions on how much to purchase as well as at what qualities. The effect of quality characteristics on consumer behavior in durable goods such as automobiles and computers as well as nondurable goods such as food has long been recognized (e.g., Waugh 1928, Houthakker 1952, Griliches 1971). However, research on incorporating quality variation into applied demand analysis is lacking. This research addresses this shortcoming. Specifically, the purpose of this chapter is twofold. First is to analyze consumer evaluation of fat in beef and second is to address the impact of fat content on beef demand.

Determination of Fat Trimming

Since income elasticities of demand are very low or negative for most food stuffs in high income countries, consumer desire for better-quality food is likely to be a main determinant of changes in per capita demand (Tracy 1980). In marketplaces, different qualities (grades) of foods are available to

consumers and are priced accordingly. As early as the 1950s, Rhodes and Kiehl (1956) claimed that grading had been promoted as a means of classifying various agricultural products in the market. Beef, for example, may be graded from fat to lean beef according to its fat content. Based on their budget constraints, consumers have different preferences for different qualities of beef. Because the marginal utility of income is a decreasing function of income (Tweeten and Mlay 1986), consumer preference (valuation) for beef at various quality levels can be illustrated as in Figure 12.1.

Figure 12.1 shows the consumer preference (valuation) curves[2] for high and low income consumers, respectively. Assuming that fat beef is of low quality and lean beef is of high quality, consumers at different income levels have different preferences on beef quality. Because of the decreasing marginal utility of income, low income consumers overestimate the value of low quality beef while high income consumers overestimate the value of high quality beef. There is an optimal fat content level, c^*, at which both low and high income consumers have the same quality valuation. Any other fat content level represents a loss to consumers since there is some discrepancy between the consumer valuations and the true quality valuation.

The difference in the beef quality valuation between two consumers implies that consumers have different indifference curves, as shown in Figure 12.2. It can be demonstrated that the price (unit value) of beef for consumers will be different if they choose different beef combinations. Figure 12.2 explains the optimal solutions of two representative consumers, high income consumer A and low income consumer B, in two dimension space.

FIGURE 12.1 Consumer Quality Valuation on Beef Quality

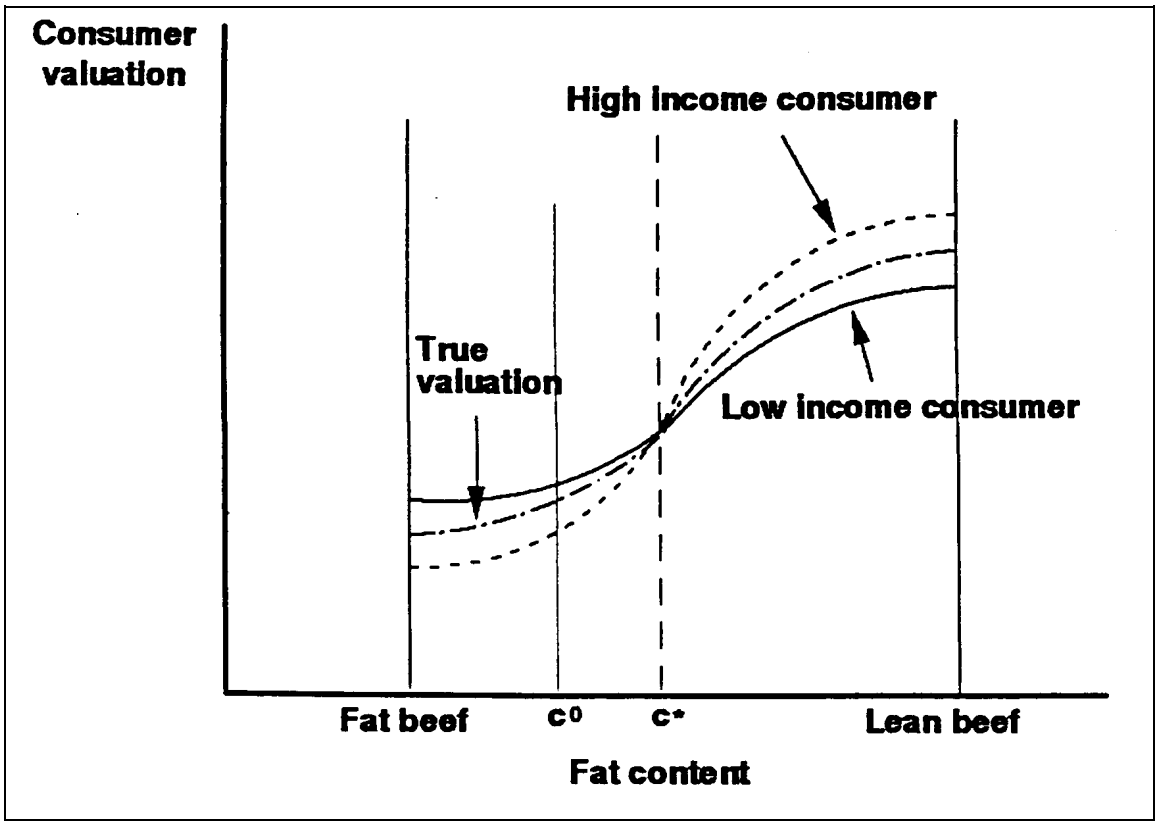
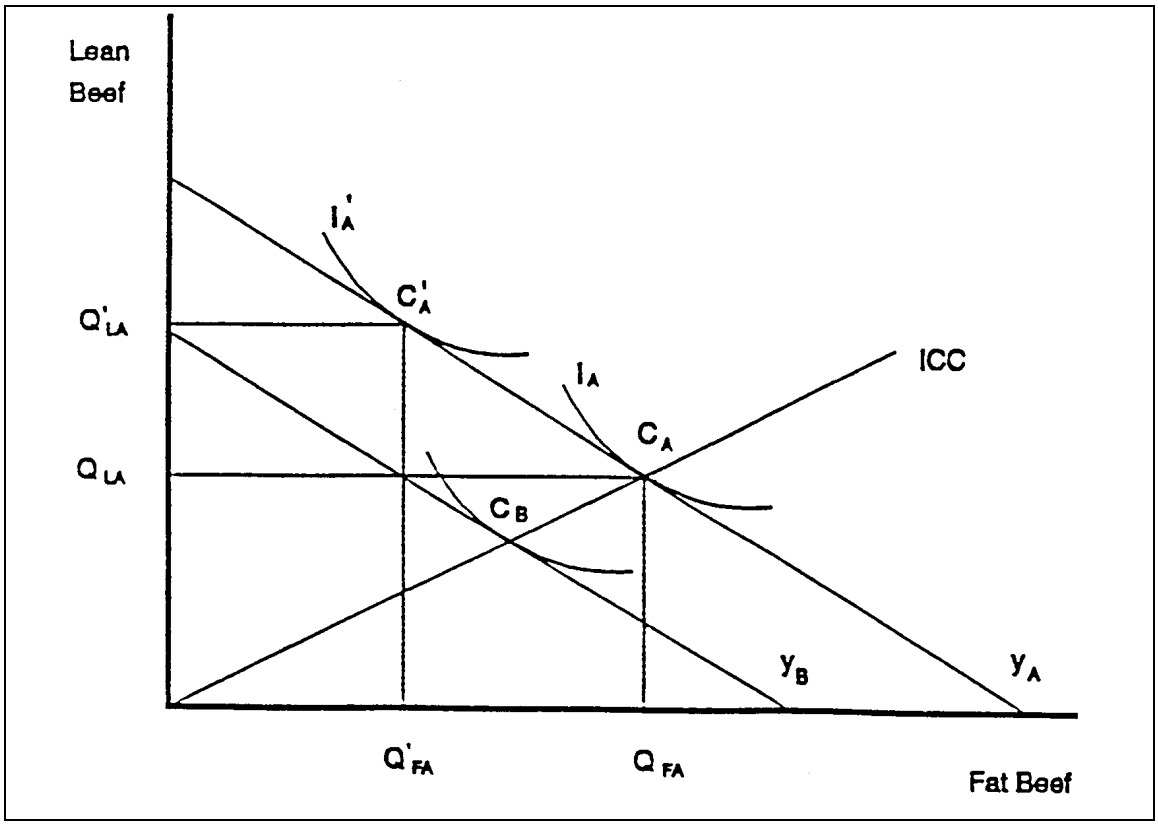


FIGURE 12.2 Consumption Combinations of Beef

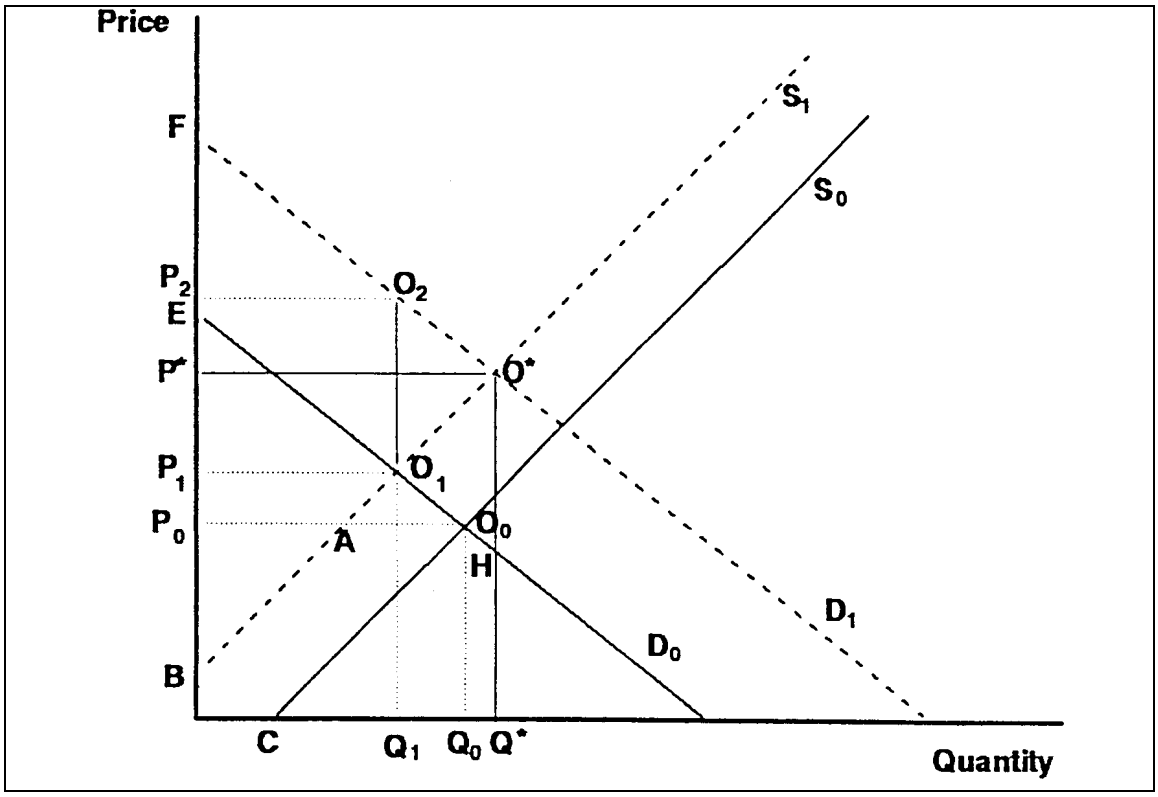


In Figure 12.2, Y_A and Y_B are budget lines for consumers A and B, respectively. ICC is an income consumption curve. Along the ICC, the proportions of lean beef and fat beef are the same for the two consumers. However, the usual case is that the high income consumer demands more lean beef and less fat beef. His/her optimal choice is at C_A' rather than C_A. In this case, consumer A will pay a higher price (unit value) than consumer B for aggregated beef.

Assuming the current fat content level is at C^0 (Figure 12.3), trimming more fat will improve consumer welfare. The welfare effects of fat trimming can be intuitively described as in Figure 12.3. The beef market is initially at the equilibrium of O_0 with demand curve D_0 and supply curve S_0. Trimming fat from beef implies that the supply curve shifts left from S_0 to S_1. This results in a change of equilibrium price from P_0 to P_1 and equilibrium quantity from Q_0 to Q_1. The loss and gain to producers are the areas of $L_P = O_0ABC$ and $G_P = O_1AP_0P_1$, respectively. As long as G_P is greater than L_P, producers will experience a net gain. According to the marginal rule, the optimal fat trimming level for producers is the point at which the marginal gain equals the marginal loss from the fat reduction.

On the consumer side, a loss of area $L_c = O_0P_0P_1O_1$ occurs because of the shift of the supply curve. However, consumers may be better off if they are willing to pay more than L_c for improving beef quality. According to Unnevehr and Bard (1993), reducing the fat content of beef is equivalent to shifting the demand curve outward from D_0 to D_1. For quantity Q_1, consumers are willing to pay P_2. Thus consumers gain the area of $G_c = O_2O_1EF$. If G_c is greater than L_c, consumers will be better off from the fat reduction. Therefore, to consumers the optimal fat trimming level is the point at which the marginal gain equals the marginal loss from the fat reduction.

FIGURE 12.3 Consumer and Producer Welfare Impacts of Fat Trimming



In fact, both producer and consumer would be better off than the above scenarios if the market equilibrium is established at O^*. In this case, producer gain will be $G_p^* = O^* AP_0 P^*$ and G_p^* is larger than G_p. Consumer gain will be $G_c^* = O^*HEF$ and G_c^* is larger than G_c. The changes of producer and consumer well-being from the fat reduction are determined by the shift and slope of the supply and demand curves. Therefore, the decision on fat trimming in the beef industry depends on consumers' perceptions of fat and the magnitude of willingness to pay for fat reduction as compared to the production cost of trimming fat. The consumer perception of fat and willingness to pay for fat reduction can be measured by own price elasticity and the fat elasticity of price. In the following section, an economic model is developed to estimate these parameters.

Model Specification

Following the approach used by Capps and Schmitz (1991), the consumer utility function can be expressed as:

(1) $$U = U(q(Z(r)))$$

where r is a vector of commodity attributes which a consumer identifies as qualities, q is a commodity vector which the consumer perceives with quality r, and Z represents how consumers perceive the quality attributes. The Marshallian demand function for good i derived from the above utility specification can be expressed as:

(2) $$q_i = q(y, p(r))$$

where y is the consumer budget and p is a price vector which associates the consumer's perception of the commodity quality. The equation implies that both demand and price are choice variables to consumers.[3] Based on these theoretical considerations, consumer perceptions of fat and demand for beef can be specified.

Since consumers are willing to pay for removing fat from beef (Unnevehr and Bard 1993), beef should be priced according to its fat content, other things equal. Therefore, demand for beef is determined by total meat expenditure; beef price, which is affected by its attributes such as fat content; prices of other meat and related products; and socio-demographic variables. The demographic variables capture the effects of other quality factors or consumer beliefs on beef demand because prices and expenditures seem inadequate in explaining observed patterns of meat consumption (Chalfant and Alston 1988) and variables such as family size and race have traditionally played a major role in the analysis of household demand behavior (Pollak and Wales 1992: 11). The empirical functional form is specified as a constant elasticity demand model:

(3) $$ln(Q_{bf}) = \alpha_0 + \alpha_1 ln(EXP) + \alpha_2 ln(P_{bf}(r_{bf})) + \sum_{i=1}^{n} \alpha_{i+2} ln(P_i) + \sum_{j=1}^{m} \alpha_{n+j+2} D_j + u$$

where Q_{bf} and P_{bf} are quantity and price of beef, respectively, EXP is meat expenditure, P_i is price of other meat i (i.e., pork, lunch meat, poultry, and fish),[4] D is a set of demographic variables, α's are parameters to be estimated, and u is the error term. This functional form is chosen because it is linear in its parameters, robust to model misspecification, and elasticities appear as parameters (LaFrance 1986).

The vector D in the demand function includes household size, educational level and race of household head, and region of resident. The household size is used to capture the effect of economies of size. The educational level and race represent consumer characteristics that affect consumer choice of specific beef items. For example, consumers at different educational levels may purchase beef of different qualities. The region of the resident captures regional differences in consumption traditions.

Based on the procedure used by Houthakker (1955) and Deaton (1988), and the hedonic methodology, the beef price is assumed to be determined by the fat content of beef, and consumer economic and socio-demographic characteristics. The empirical specification is expressed as:

(4) $$ln(P_{bf}(r_{bf})) = \beta_0 + \beta_1 ln(FAT) + \beta_2 ln(FC) + \sum_{j=1}^{d} \beta_{2+j} D_j + e$$

where FAT is fat content of beef, FC is total food cost, D is a vector of consumer demographic variables, β's are parameters to be estimated, and e is the error term.

The β_1 is interpreted as the fat elasticity of the beef price and is expected to be negative representing consumers' willingness to pay for fat reduction. In addition, this parameter is important in determining optimal fat trimming schemes. Compared with the α_2 parameter in the beef demand function, own price elasticity of beef, a larger β_1 in absolute value implies that the beef industry may enhance revenue by marketing leaner beef. Demographic variables are used to capture consumer perceptions of beef quality.

Total food cost (FC) (including at- and away-from-home food expenditures) rather than total meat expenditure, EXP in equation (1), is used to capture consumer perceptions of quality. The FC is used as a proxy of consumer income based on the belief that beef quality is related to FC more directly than to income. A positive β_2 is plausible so that high income consumers purchase more expensive (high quality) beef items. A quality elasticity of beef can be defined as (Houthakker 1952):

(5) $$E_q = \frac{P_{bf}}{FC} \frac{\partial P_{bf}}{\partial FC} = \beta_2.$$

Equations (1) and (2) comprise a recursive simultaneous equation system and can be estimated by a two-stage least squares (2SLS) procedure if the system is identified.

Data

Data used in this study are from the 1987-88 Nationwide Food Consumption Survey (NFCS) which was conducted between April 1987 and August 1988 and sponsored by the United States Department of Agriculture. The survey contains food consumption and socio-economic and demographic information on 4,273 housekeeping households[5] in the 48 conterminous states in the United States. Among those, 3,603 households who consumed beef during the survey week are used for the analysis.[6] Five meats (i.e., beef, pork, lunch meat, poultry, and fish) are defined as the consumption bundle due to expected cross substitutional and complementary relationships. Lunch meat includes hot dogs, frankfurters, and other lunch meats except boiled ham and roast beef.

The selected socio-demographic variables are standard household size, educational level and race of household head, food stamp participation, region and urbanization area of the resident, and household head status. Definitions of these and selected continuous variables (meat expenditure, total food cost, fat content of beef, beef consumption, and prices of the five meats) and their selected sample statistics are presented in Table 12.1.

Treatment of Missing Prices

During the survey week, not all of the 3,603 households consumed all five meats. Some prices are unobserved for some households who did not consume a meat during the survey week. In addressing this issue, there are several approaches proposed in the literature. One approach is to approximate the missing prices by an inverse semi-log specification. The inverse semi-log is used to avoid negative predicted prices. The missing prices are predicted by regressing the logged available prices on other available independent variables. One caveat of this approach is the introduction of random factors into the demand model. Additionally, the model for predicting the missing prices is likely to be incorrect (Pudney 1989).

Two simpler and most commonly used ways of treating missing prices are discarding the observations that have missing prices or replacing the missing prices with "appropriate" sample means. It is often arbitrary to select which method to use. In this study, there are only 813 households that consumed all five meats during the survey period. Severe sample bias may occur if the observations which have missing prices are discarded. Therefore, the missing prices are replaced by regional means in this study.[7] The regional means are calculated based on the region and urbanization area of residents and educational level of the household head.

The region and urbanization area of residents are used for computing the sample means because they may reflect price differences due to marketing situations and regional consumption traditions. The educational level of household head determines which stores consumers are more likely to purchase from. Different stores may charge different prices for a meat because of quality differences, shopping environment, and other services such as packaging, cleaning, and cutting.

TABLE 12.1 Variable Definition and Selected Sample Statistics (N[a] = 3,603)

Variable	Definition	Mean
EXP ($/wk)	Per capita expenditure on five meat commodities	8.27 (5.60)[b]
FC ($/wk)	Per capita total food cost (at- and away-from-home)	91.72 (561.29)
FAT (g)	Fat contents per lb. of beef	88.18 (16.45)
Q_{bf} (lb/wk)	Per capita beef consumption	1.76 (1.40)
P_{bf} ($/lb) (N = 3,603)	Beef price defined as dividing expenditure by quantity	1.91 (0.85)
P_{pk} ($/lb) (N = 2,983)	Pork price defined as dividing expenditure by quantity	2.08 (0.87)
P_{lm} ($/lb) (N = 2,762)	Lunch meat price defined as dividing expenditure by quantity	2.11 (0.90)
P_{pt} ($/lb) (N = 3,118)	Poultry price defined as dividing expenditure by quantity	1.40 (1.05)
P_{fh} ($/lb) (N = 2,242)	Fish price defined as dividing expenditure by quantity	2.92 (1.74)
SFS	Standard family size (21 meal equivalent person)	2.56 (1.34)
ED1	1 if household head completed less than 9 years of school, 0 otherwise	0.133
ED2*	1 if household head completed high school, 0 otherwise	0.493
ED3	1 if household head completed 1-4 years of college, 0 otherwise	0.307
ED4	1 if household head completed more than 4 years of college, 0 otherwise	0.068
RA1	1 if household head is white, 0 otherwise	0.851
RA2*	1 if household head is not white, 0 otherwise	0.149
RS	1 if household currently receives food stamps, 0 otherwise	0.075
NRS*	1 if household does not receive food stamps, 0 otherwise	0.925

(continues)

TABLE 12.1 Variable Definition and Selected Sample Statistics (N[a] = 3,603) (continued)

Variable	Definition	Mean
FEM	1 if household headed by female only, 0 otherwise	0.228
NFEM*	1 if household not headed by female only, 0 otherwise	0.772
NE	1 if Northeast region resident, 0 otherwise	0.198
MW	1 if Midwest region resident, 0 otherwise	0.273
SOUTH	1 if South region resident, 0 otherwise	0.347
WEST*	1 if West region resident, 0 otherwise	0.182
URB1	1 if household lives in central city, 0 otherwise	0.221
URB2*	1 if household lives in suburban area, 0 otherwise	0.478
URB3	1 if household lives in non-metro area, 0 otherwise	0.301

[a]N denotes number of observations.
[b]Number in parenthesis is standard deviation.
*Denotes the base category for estimation.

Results and Discussion

The beef demand and price equations were estimated by two-stage least squares (2SLS). The results are statistically plausible (Table 12.2). For the beef demand equation, 13 out of 15 (86.7 percent) parameters are statistically significant at the 0.05 level. The R^2 is 0.40 which is acceptable for an analysis of cross-sectional data. Eleven out of 15 (73.3 percent) parameters in the beef price equation are statistically significant at the 0.01 level. The price equation has a R^2 of 0.19. Cox and Wohlgenant (1986) used a similar specification for vegetable prices and reported the R^2 s of 0.05, 0.03, and 0.04 for fresh, canned, and frozen vegetables, respectively. Regarding their very low R^2 s, they concluded that the quality impact on price was small for vegetables and indicated that physical characteristics that reflect commodity qualities should be included. Results of this study suggest that fat in beef is an appropriate physical attribute that consumers identify as quality.

The estimated demand elasticities of beef with respect to expenditure and its own price are 0.79 and -0.33. This is consistent with the results of Capps and Schmitz (1991) who emphasized the importance of health and nutrition information for the demand for food. As early as the 1960s, Tomek (1965) pointed out that beef has become less price elastic and partially attributed this to quality changes in the product. The inelastic demand elasticity suggests that consumers may be more interested in beef quality rather than quantity (Menkhaus et al. 1993). The inelastic own price elasticity provides economic support of trimming fat from beef.

The estimated cross price elasticities show that all the meats are complements although they are very inelastic in respect to cross prices. A possible explanation is that quality variations of meat outweigh price effects for consumers in the 1990s (Wesenberg 1990). If an individual consumes low-quality beef such as not-well-trimmed and bone-in beef, he/she is also more likely to consume low-quality pork. If the low-quality commodities are represented by large quantities for reasons such as not-well-trimmed and bone-in meat, the complements relationship may be present. Moreover, consumers may switch

TABLE 12.2 Estimation Results of Beef Demand and Price Equations by 2SLS

Variable	Demand Equation		Price Equation	
	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
Constant	-0.774*	0.062	2.607*	0.129
ln (EXP)	0.792*	0.022	--	--
ln (P_{bf})	-0.328*	0.099	--	--
ln (P_{pk})	-0.109*	0.036	--	--
ln (P_{lm})	-0.105*	0.033	--	--
ln (P_{pt})	-0.065*	0.020	--	--
ln (P_{fh})	-0.075*	0.028	--	--
ln (SFS)	0.060*	0.019	-0.044*	0.012
ED1	-0.003	0.032	-0.029	0.018
ED3	-0.112*	0.024	0.052*	0.013
ED4	-0.139*	0.043	0.101*	0.024
RA1	0.063**	0.030	0.053*	0.018
NE	-0.132*	0.033	0.068*	0.019
MW	0.066**	0.032	-0.093*	0.018
SOUTH	0.010	0.030	-0.024	0.017
ln (FC)	--	--	0.059*	0.008
ln (FAT)	--	--	-0.501*	0.027
FEM	--	--	-0.024	0.016
RS	--	--	-0.073*	0.023
URB1	--	--	0.015	0.015
URB3	--	--	-0.061*	0.014
R-Square	0.40		0.19	

Note: The superscripts * and ** correspond to levels of statistical significance of 1 and 5 percent, respectively.

away from meat to other foods such as vegetables and fruits due to their growing health concerns. This offers another possibility of presenting a complementary relationship between meats. This finding appears in conflict with those of previous studies. Capps and Schmitz (1991) and Spreen and Gao (1993) found meat and related products to be very inelastic to cross prices with a majority of the commodities as substitutes. This may be because Capps and Schmitz used time series data (1966-88), while Spreen and Gao used more disaggregated data such as steak and roasts.

Per capita demand for beef declines as household size increases. This indicates that large households may consume more variety of meats owing to possible taste differences. The estimated coefficients of educational levels indicate that consumers with more years of education consume less beef than consumers with few years of education. White households tend to demand more beef than do the other races. Compared with consumers in the West region, those in the Northeast demand less while Midwest consumers demand more beef. Demand for beef is not significantly different between consumers in the West and South regions.

The coefficient for food cost in the price equation is statistically significant and positive as expected. The positive estimate indicates that high income consumers demand high quality products. This is consistent with the findings of previous studies. Black (1952) concluded that high income consumers paid higher prices for food than low income consumers. Cox and Wohlgenant (1986) found high income consumers pay a higher price for fresh vegetables than low income consumers using the 1977-78 NFCS. Consistent with Unnevehr and Bard (1993), the elasticity of price with respect to fat content is statistically significant and negative (-0.501). This implies that fat is negatively valued. Consumers are willing to pay more for reducing fat content in beef. This elasticity is larger than the own price elasticity of beef (-0.328) in absolute value although both elasticities are less than unity. This relationship implies that trimming extra fat may improve the net revenue of the beef industry.

Economies of size are present as is shown by the significant and negative coefficient on standard household size. Similar results were found by Cox and Wohlgenant (1986). They reported that large households pay low prices for fresh, canned, and frozen vegetables. The estimated parameters for educational levels indicate that consumers with more years of schooling pay a higher price for beef than consumers with few years of schooling. Cox and Wohlgenant reported that consumers who have completed college demand higher quality of canned vegetables than do the less-educated consumers. A comparison of the parameters with their associated parameters in the demand equation indicates highly-educated consumers substitute quality for quantity.

White households pay a higher price for a unit of beef than other races. Similarly, Cox and Wohlgenant found nonblack households pay higher prices for fresh and canned vegetables. In addition, white households also demand more beef than do the other races as shown by the significant parameter in the demand equation. This finding has important implications to the beef industry. Because consumers demand more high quality beef, producing and/or marketing leaner beef may enhance the profit of the beef industry. Compared with the West region households, households pay more in the Northeast and less in the Midwest regions for a unit of beef. This explains why consumers demand less beef in the Northeast and more beef in the Midwest regions as seen in the demand equation.

The parameter for the food stamp variable is statistically significant and negative. This implies that food stamp recipients consume lower quality beef than do other households. The results also indicate that beef quality is lower for households living in non-metro areas than those living in other areas.

Conclusion

The relationship between consumer perceptions of fat and demand for beef is specified in an economic model. The model is applied to a cross-sectional data set from the 1987-88 Nationwide Food Consumption Survey. Consistent with previous studies such as Capps and Schmitz (1991), the results indicate that beef demand is rather inelastic to meat expenditure and its own price. These inelastic elasticities and the estimated coefficients of the demographic variables suggest that consumers substitute quantity for quality. This finding is important for beef production and marketing. For example, producing and marketing leaner (high-quality) beef may be a key avenue for the beef industry to enhance profit. The finding of a complementary relationship among meats is quite different from the general assumptions and results of previous studies. This may raise a challenge for conducting cross-sectional demand analyses and understanding consumer food consumption behavior.

The fat elasticity of beef price suggests that consumers are willing to pay a higher price for reducing fat content in beef. Furthermore, the fat elasticity is larger than the own price elasticity of beef demand in absolute magnitude. Thus, the beef industry could potentially achieve a higher profit if more fat is trimmed. Per capita total food cost, family size, region and urbanization area of resident, food stamp participation, educational level, and race of household head are major determinants of consumer

perceptions of fat in beef. These results are useful for initiating appropriate marketing strategies such as market segmentation. For example, more fat should be trimmed in the Northeast region and the regions and/or areas with more highly educated consumers.

Notes

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[2]The consumer valuation curve is a continuous function of the commodity quality attribute (Zusman 1967).

[3]For more theoretical background on price as a consumer choice variable, the reader is referred to Houthakker (1952), Deaton (1988), and Pudney (1989).

[4]The price of other meats is not assumed to be a function of quality attributes due to data limitations and requirements of too many assumptions in economic modeling.

[5]The housekeeping household is defined as at least one member having ten or more meals from the household food supply during the survey week.

[6]The deletion of households that did not consume beef during the survey week may introduce sample bias. However, the inclusion of these households in the analysis requires a number of assumptions in model specification and estimation.

[7]For the appropriateness of this approach, the reader is referred to Cox and Wohlgenant (1986) for details.

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