Journal of Agricultural and Resource Economics, 18(2): 239–250

Quantifying the Effects of New Product Development: The Case of Low-Fat Ground Beef

Gary W. Brester, Pascale Lhermite, Barry K. Goodwin, and Melvin C. Hunt

Low-fat ground beef (LFGB) is a new product designed to be as palatable as beef products that contain significantly higher levels of fat. A hedonic model shows that each unitary increase in the leanness of ground beef products carries a price premium of $.0206/lb. If LFGB garners a 10% share of the ground beef market, the retail price of all ground beef products will increase by $.01/lb. and consumption will increase by 39.75 million lbs. The price of commercial cows will increase by $.56/cwt. Price, quantity, and welfare measures are magnified as the market share captured by LFGB increases.

Key words: low-fat ground beef, nonfed cattle prices, welfare effects.

Introduction

The market effects of the introduction of a new consumer product are often difficult to predict. Market surveys (e.g., Menkhaus, Whipple, and Field) and test marketing are two methods used to anticipate the effects of introducing a new product. However, surveys are not perfect predictors of actual market behavior and test marketing data are not always available. For example, many producer groups actively promote products through generic advertising and may be unable to test market specific products if processors possess the property rights to these new products. In addition, promoting such products entails moving from generic advertising to brand advertising. Many producer groups are not willing or able to make such a change. Nonetheless, the introduction of new food products does affect agricultural producers and may alter the effectiveness of producer groups' demand enhancement efforts.

The development and market introduction of low-fat ground beef (LFGB) is an example of a new product that was developed with funds from a producer group (i.e., the Cattlemen's Beef Promotion and Research Board via the Beef Industry Council of the National Live Stock and Meat Board), but is produced and sold as a branded commodity by meat processing firms. The term "low-fat ground beef" refers to ground beef that contains flavor-enhancing ingredients (e.g., carrageenan, oat bran, salt) which are used as a substitute for fat. Although a variety of survey and test market studies relating to the acceptance of LFGB have been conducted (National Live Stock and Meat Board; Dunkelberger et al.), the ultimate market effects of this new product remain subject to speculation. While this new product is likely to affect the entire beef industry, its effect on cattle prices is of particular interest to cattle producers because they supplied research funding for its initial development. Therefore, this article presents an analysis of the introduction of LFGB and its effects on consumers, meat processors, and cattle producers.

Gary Brester is an assistant professor in the Department of Agricultural Economics, Kansas State University; Pascale Lhermite is a graduate of Ecole Superieure D'Agriculture De Purpan Toulouse; Barry Goodwin is an associate professor in the Department of Agricultural and Resource Economics, North Carolina State University; and Melvin Hunt is a professor in the Department of Animal Sciences and Industry, Kansas State University.

This is Contribution No. 93-565-J of the Kansas Agricultural Experiment Station, Manhattan, Kansas.

The authors wish to acknowledge the helpful comments provided by Andy Barkley, Bob Campbell, Jim Mintert, Bob Moran, Mike Wohlgenant, and two anonymous reviewers. The support of the Kansas Agricultural Experiment Station is greatly appreciated.

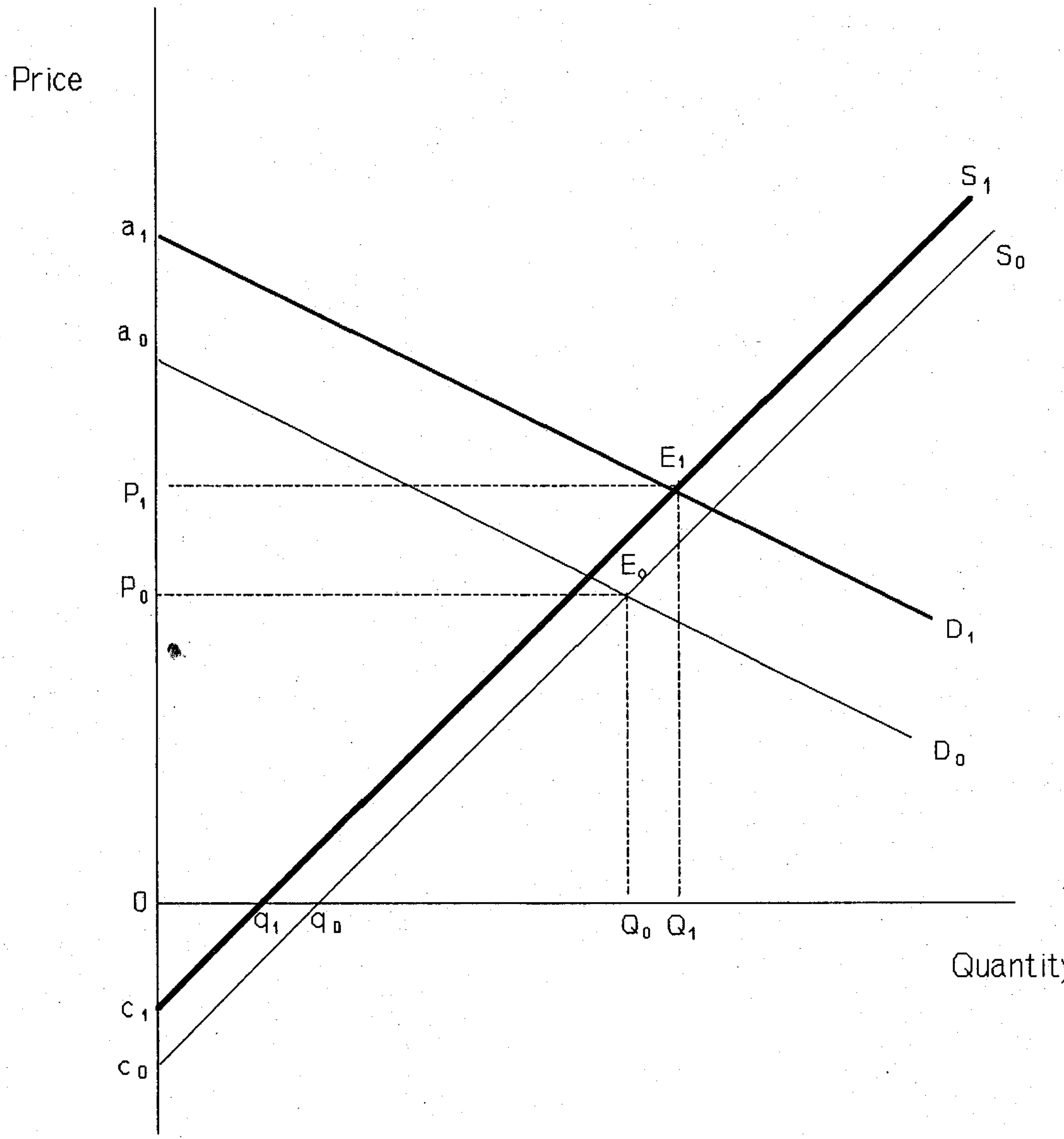

Figure 1. The market effects at the retail level of the introduction of low-fat ground beef

The Development and Production of Low-Fat Ground Beef

The Beef Promotion and Research Act of 1985 authorized the U.S. beef industry to develop and implement informational programs to enhance consumer demand for beef. Funds for a variety of research and promotional projects are obtained from per-head check-off assessments. Between 1987 and 1988, the National Live Stock and Meat Board allocated $373,000 among several research institutions (Auburn University, Kansas State University, University of Illinois, Webb Technical Group, and ABC Research Corporation) to develop a low-fat ground beef product that remained palatable while satisfying consumer concerns regarding dietary fat (Pinkerton). Very lean ground beef (less than 10% fat, but without added flavor-enhancing ingredients which replace fat) is not palatable to most consumers. Studies indicate that consumers prefer the taste of 80% lean ground beef, but also are concerned with intakes of dietary fat ("The Men Behind McLean"; "LFGB Enters the Industry's War on Fat").

Researchers at Auburn University have developed a low-fat ground beef formulation that has been adopted by portions of the food service industry and, on a limited scale, by McDonald's franchises. Their formula uses carrageenan (a seaweed derivative) to replace fat and maintain palatability. Other formulations of LFGB are being used by other firms. It is possible that LFGB may have dramatic effects on the beef market because over 40% of all beef consumption is in the form of ground beef (Brester and Wohlgenant).

Modeling the Market Effects of the Introduction of Low-Fat Ground Beef

Figure 1 represents the market demand and supply functions for all ground beef products at the retail level. Prior to the introduction of LFGB, D_0 is the consumer aggregate demand curve for all ground beef products, and S_0 is the market supply curve (including imports) of ground beef. The supply curve represents the production behavior of beef packers, processors, grinders, and restauranteurs. If the supply curve is price inelastic, it will intersect the quantity axis. Market equilibrium occurs at price P_0 and quantity Q_0.

The introduction of LFGB affects both the supply and demand for ground beef. Assuming that consumers value reductions in the dietary fat content of ground beef, the introduction of LFGB shifts the aggregate market demand curve of all ground beef products. This shift is represented as a parallel, vertical shift from D_0 to D_1 (Unnevehr). Because LFGB is more expensive to produce than other ground beef products, the market supply curve will also shift upwards from S_0 to S_1. It is not known if the production of LFGB has differential effects on low-cost versus high-cost producers of ground beef. Therefore, the shift in supply is represented by a parallel movement of the supply curve (Rose).

The shifts in demand and supply generate a new equilibrium at P_1 and Q_1. The new equilibrium price will be higher than the original price. However, the direction of change in the equilibrium quantity is ambiguous and depends upon the relative magnitudes of the demand and supply shifts. In this example, the demand shift is larger than the supply shift, so that Q_1 is larger than Q_0.

The size of the demand shift caused by the introduction of LFGB at the retail level depends upon several factors: (*a*) the overall acceptance of LFGB by consumers, (*b*) the quantity of ground beef substituted for other meat or nonmeat products, and (*c*) the amount of substitution among ground beef products. The supply shift is determined by the effect of LFGB's higher production costs on the aggregate market supply curve.

A Model of the Primary and Derived Market Levels in the Ground Beef Industry

The following structural model is used to estimate the price, quantity, and welfare effects of the introduction of LFGB:

Retail Level

(1) Primary Demand: $Q_d^G = f_1(P^G, \mathbf{P}, \mathbf{Y})$

(2) Derived Supply: $Q_s^G = f_2(P^G, P^N, \mathbf{W})$

(3) Market Clearing: $Q_d^G = Q_s^G = Q^G$

Farm Level

(4) Derived Demand: $Q_d^N = g_1(P^N, P^G, \mathbf{X})$

(5) Primary Supply: $Q_s^N = g_2(P^N, \mathbf{Z})$

(6) Market Clearing: $Q_d^N = Q_s^N = Q^N$.

Equation (1) represents the consumer demand for ground beef (Q_d^G) as a function of the price of ground beef (P^G), a vector of prices of substitute products (**P**) (e.g., the price of poultry, pork, and table cuts of beef), and a vector of exogenous demand shifters (**Y**) which includes such factors as income and health concerns.

The retail supply of ground beef [equation (2)] is a derived supply function that is determined by the profit-maximizing decisions of meat packers, processors, and restaurateurs. The quantity supplied of ground beef (Q_s^G) is a function of the price of ground beef (P^G), the price of nonfed cattle (P^N) which is the farm product generally used to produce lean ground beef (Cattle-Fax), and a vector of exogenous supply shifters (**W**).[1]

Equation (4) represents the derived demand for nonfed cattle (Q_d^N) as a function of the price of nonfed cattle (P^N), the price of ground beef (P^G), and a vector of exogenous derived demand shifters (**X**). The primary supply of nonfed cattle (Q_s^N) is presented in equation (5) as a function of the price of nonfed cattle (P^N), and a vector of exogenous primary supply shifters (**Z**).

A Hedonic Model of Ground Beef Prices

Low-fat ground beef is a new product that only recently has become available to consumers. Thus, demand for this new product is unknown. Usual techniques for demand analysis are not applicable in this case for two reasons. First, quantity data do not exist for the consumption of disaggregated ground beef products. Second, market price data are not available for LFGB because it has only recently been introduced into the market. In addition, much of the initial consumption of LFGB has occurred in the fast-food and food service industries, which adds to the difficulty of identifying its price.

Ground beef products are labeled and sold based upon fat content. Fat content also influences the palatability of ground beef. Presumably, market prices reflect these differences. Thus, leanness is a characteristic of ground beef that influences its price and is represented in equation (1) as an element of **Y**. Estimates of the price premium associated with leanness in ground beef products can be obtained from a hedonic model of the form:

$$(7) \qquad DPRICEG_{it} = \alpha_0 + \alpha_1 LEAN_i + \alpha_2 DINC_t + \epsilon_{it} \qquad i = 1, \ldots, m; \quad t = 1, \ldots, n,$$

where *DPRICEG* is the deflated price of *m* ground beef products over *n* time periods, *LEAN* is the leanness of each of the *m* ground beef products, *DINC* is deflated U.S. monthly total personal consumption expenditures, and ϵ is a normally distributed, time-wise independent error term.

Retail prices of disaggregated ground beef products are not available. Therefore, monthly wholesale prices of 75%, 85%, and 90% lean, boneless fresh beef (from which ground beef is produced) in cents/lb. for the five-year period 1986–90 were obtained from the *Livestock, Meat, and Wool Market News* [U.S. Department of Agriculture (USDA)] and used as proxies for the retail price. Thus, 75, 85, and 90 are the values used for *LEAN*. Monthly personal consumption expenditure data also are unavailable. Therefore, quarterly data were obtained from *Economic Indicators* (Council of Economic Advisors) and interpolated using the EXPAND program in SAS (SAS Institute, Inc.) to obtain monthly estimates. The price and income variables are deflated by the consumer price index for food (December 1992 = 1.0) obtained from the *Survey of Current Business* (U.S. Department of Commerce). The price index is a measure of the general food price level over time.

Equation (8) presents the OLS regression results of the hedonic model:

$$(8) \qquad \underset{}{DPRICEG} = \underset{(-12.12)}{-137.61} + \underset{(31.68)}{2.06LEAN} + \underset{(7.84)}{.28DINC}$$

$$\bar{R}^2 = 0.84, \quad S_y = .057, \quad \bar{Y} = 1.18, \quad \text{DF} = 177,$$

where $\bar{R}^2$ is the adjusted *R*-squared, S_y is the standard error of the estimate, $\bar{Y}$ is the mean of the dependent variable, DF is the degrees of freedom, and values in parentheses are *t*-values of the parameter estimates. White's test of the null hypothesis of the absence of heteroskedasticity yielded a test statistic of 11.074. The χ^2_5 critical value at the .05 level is 11.071. Therefore, the null hypothesis is rejected. Thus, the reported t-values have been calculated using the standard errors from White's heteroskedastic-consistent covariance matrix.

The parameter estimate for *LEAN* indicates that a unitary increase in the leanness of ground beef carries a price premium of \$.0206/lb. For example, 90% lean ground beef has a price premium of \$.103/lb. (i.e., \$.0206 × 5) over 85% lean ground beef.

Estimating the Impact of Low-Fat Ground Beef on Retail Demand

Low-fat ground beef will be more highly valued than existing ground beef products because of its lower fat content if it is as palatable as 80% lean ground beef. Therefore, the introduction of LFGB creates a substitute for 80% lean ground beef. It is also possible that some consumers who previously have not consumed ground beef because of concerns regarding its fat content may consume LFGB. The size of this expanded market (or new consumer) effect is difficult to predict. Thus, the remainder of this article considers only the substitution effect among ground beef products while recognizing that the total market impacts may be underestimated.

The introduction of LFGB is represented by a vertical shift in the demand curve from D_0 to D_1 in figure 1. The size of this shift depends upon the ground beef market share captured by LFGB. The market share likely to be garnered by LFGB is unknown. However, assume that LFGB gains a 10% market share of all ground beef products. (The sensitivity of the results to this assumption will be considered later.) According to a recent study (Cattle-Fax), retailers sell 45% of ground beef as 73–79% lean, 50% as 80–89% lean, and 5% as 90–94% lean.[2] These market shares are relevant prior to the introduction of LFGB. Using the mean quantity levels of each ground beef product from the 1986–90 period, the weighted average aggregate level of leanness of ground beef products is currently 80.75%. The introduction of LFGB generally will affect the market share of the 80–89% lean category because LFGB is designed to be as palatable as 80% lean ground beef ("The Men Behind McLean"; "LFGB Enters the Industry's War on Fat"). Therefore, any substitution by consumers away from 80–89% lean ground beef towards LFGB will cause the market share of 80–89% lean ground beef to decline. Assuming that LFGB gains a 10% share of the total ground beef market, the 80–89% lean product's market share will decline to 40%. Thus, the introduction of LFGB will cause the weighted average leanness of all ground beef to increase from 80.75% to 81.75%.

The increase in the aggregate leanness of ground beef is caused by a substitution from the consumption of 80–89% lean ground beef to the new LFGB product. The hedonic model indicates that each unitary increase in leanness carries a price premium of \$.0206/lb. Assuming parallel shifts and a 10% market share, the introduction of LFGB causes the aggregate demand for ground beef to shift vertically by \$.0206/lb. as a result of the weighted average level of leanness increasing by one unit. The sensitivity of this demand shift to the assumed market share captured by LFGB will be evaluated in a following section.

Estimating the Impact of Low-Fat Ground Beef on Retail Supply

It is more costly to produce LFGB than other types of ground beef because of additional ingredient and labor requirements. Thus, the introduction of LFGB shifts the aggregate supply curve for ground beef upwards and to the left. This shift is represented in figure 1 as a movement from S_0 to S_1. Estimating the size of this shift is difficult because of differing LFGB formulations, final fat contents, and scale economies. However, a major LFGB manufacturer (Miller Meats) indicates that it costs approximately \$.03/lb. more to produce 95% lean LFGB than to produce 90% lean ground beef. Assuming that the production of LFGB does not affect the marginal cost of producing other ground beef products and that LFGB garners a 10% market share, the vertical shift of the aggregate supply curve amounts to \$.003/lb. (i.e., \$.03/lb. × .10).

Estimating Changes in Retail Prices and Quantities

Calculating changes in equilibrium retail prices and quantities as a result of the introduction of LFGB requires the identification of the slope and intercept parameters for the curves in figure 1. For small price changes, linear functions should closely approximate the true (but unknown) functional forms. The slope and intercept parameters for D_0 can be derived using the means of the price and quantity data for P_0 and Q_0, and an estimate of the own-price elasticity of demand for ground beef. Brester and Wohlgenant estimate this elasticity to be −1.02. However, this estimate assumes that prices of other meats and nonmeat products remain constant as the price of ground beef changes. Because other meats are substitutes for ground beef, it is likely that these markets also will be affected by the introduction of LFGB. Therefore, it is more appropriate to use the own-price elasticity of the total response demand function for ground beef (Buse). Such a function explicitly recognizes feedback effects from other markets. A lower bound (in absolute value) of the total response demand elasticity can be calculated by assuming that the supplies of competing meats and nonmeat products are perfectly inelastic (Lemieux and Wohlgenant). Using estimates of own- and cross-price elasticities from Brester and Wohlgenant, the lower bound for the total response demand elasticity is calculated to be −.69. Thus, the own-price total response demand elasticity is between −.69 and −1.02. The midpoint of this range (−.86) will be used to illustrate the impact of LFGB on the retail and cattle producer markets. The sensitivity of the results to the chosen demand elasticity estimate is considered in a later section.

Slope and intercept parameters can be derived for the supply of ground beef at the retail level (S_0) if the own-price elasticity of supply is known. An own-price elasticity obtained by estimating equation (2) would ignore feedback effects among the markets. For example, nonfed cattle represent the primary farm-level input used to produce ground beef. Thus, changes in the price of nonfed cattle which result from the introduction of LFGB have a feedback effect on the supply of ground beef at the retail level. This feedback effect is captured by using a general equilibrium supply curve.

Thurman and Wohlgenant present a method for estimating a general equilibrium demand curve. As an analogue to their approach, a general equilibrium supply curve is found by first equating equations (4) and (5) and solving for P^N:

$$P^N = h_1(P^G, \boldsymbol{X}, \boldsymbol{Z}). \tag{9}$$

The general equilibrium supply curve includes the feedback effect of P^N on P^G. This effect is accounted for by substituting equation (9) into equation (2) so that the general equilibrium supply curve is given by:

$$Q_s^G = h_2(P^G, \boldsymbol{W}, \boldsymbol{X}, \boldsymbol{Z}). \tag{10}$$

The elements of $\boldsymbol{W}$ consist of the lagged production of ground beef, which represents asset fixity in the meat processing industry, and the price of marketing inputs used to process and market ground beef. Marketing inputs include such items as labor, packaging materials, transportation, energy, and operating capital. The price of beef by-products is an element of $\boldsymbol{X}$. By-products are an important source of revenues for beef processors and thus affect the derived demand for slaughter cattle (Brester and Marsh). $\boldsymbol{Z}$ consists of shifters of the primary supply of nonfed cattle. Nonfed steers and heifers, cull cows, and bulls are generally used to produce ground beef products that are at least 80% lean (Cattle-Fax). Increases in the cost of either maintaining a cow herd or producing nonfed steers and heifers (e.g., higher roughage feed prices) will increase nonfed slaughter. The price of hay is used as a proxy for roughage feed costs. The price of feeder calves is another supply shifter because calves are the primary output of the breeding stock. Consequently, increases in the price of feeder calves would cause a decrease in cow and bull culling activity and a reduction in nonfed slaughter. A one-period lag of nonfed cattle slaughter is also included as a supply shifter to reflect the dynamics of the cattle cycle (Brester and Marsh).

Equation (11) presents a linear representation of the ground beef general equilibrium supply function described by equation (10):

$$(11) \quad GBPROD_t = \beta_0 + \beta_1 DPGB_t + \beta_2 DIMC_t + \beta_3 DPFEEDST_t + \beta_4 DPHAY_t + \beta_5 DPBY_t + \beta_6 NONFEDSL_{t-1} + \beta_7 GBPROD_{t-1},$$

where *GBPROD* is the domestic production of ground beef, *DPGB* is the deflated retail price of ground beef, *DIMC* is a deflated index of marketing costs, *DPFEEDST* is the deflated price of feeder steer calves, *DPHAY* is the deflated price of hay, *DPBY* is the deflated price of beef by-products, and *NONFEDSL* is the number of nonfed steers, nonfed heifers, cows, and bulls slaughtered.

Equation (11) is estimated using two-stage least squares (2SLS) to account for joint dependency between the price and production of ground beef. Annual data from 1962–89 are used. Data for the carcass-weight domestic production of ground beef (in million lbs.) were obtained from Brester and Wohlgenant. A ground beef price index was obtained from various issues of *Food Consumption, Prices, and Expenditures* (USDA) and used for *DPGB*. An index of marketing costs which represents a weighted average of input prices used in food processing was used for *DIMC* (Harp). The price of feeder steers (in dollars/lb.) and the price of beef by-products were obtained from various issues of *Livestock and Poultry Situation and Outlook Report* and *Livestock and Meat Statistics* (USDA). The price of hay (in dollars/ton) was taken from various issues of *Feed Situation and Outlook Report* (USDA). Numbers of cows and bulls slaughtered (in thousands of head) were collected from various issues of *Livestock Slaughter* (USDA) and added to the numbers of nonfed steers and heifers slaughtered (Western Livestock Marketing Information Project) to obtain *NONFEDSL*. All prices are deflated by the consumer price index (1967 = 100).

Equation (12) presents the 2SLS regression results of equation (11):[3]

$$(12) \quad \begin{aligned} GBPROD_t = \underset{(30.9)}{3{,}305} &+ \underset{(3.98)}{5{,}264}DPGB_t - \underset{(-1.31)}{1{,}437}DIMC_t \\ &- \underset{(-5.90)}{21{,}337}DPFEEDST_t + \underset{(.86)}{2{,}036}DPHAY_t + \underset{(.50)}{4{,}134}DPBY_t \\ &- \underset{(-1.29)}{.047}NONFEDSL_{t-1} + \underset{(8.87)}{.828}GBPROD_{t-1} \end{aligned}$$

$$\bar{R}^2 = 0.91, \quad S_y = 248.40, \quad \bar{Y} = 8{,}755.2, \quad DF = 19, \quad \pi^2 = 3.58,$$

where π^2 is Godfrey's test statistic for the null hypothesis of no serial correlation in dynamic simultaneous equation models. The test statistic has a central χ^2 distribution. The critical value for one degree of freedom at the .05 level is 3.84. Thus, the null hypothesis of the absence of serial correlation cannot be rejected. At the means, the own-price general equilibrium supply elasticity (ϵ_r) is .59. This elasticity estimate is used to calculate the slope and intercept terms for S_0 in figure 1.[4]

Shifts in the aggregate demand and supply of ground beef generate a new equilibrium price, P_1, and a new equilibrium quantity, Q_1 (fig. 1). Solving the supply and demand functions simultaneously yields P_1 equal to \$1.40/lb. and Q_1 equal to 8,985 million lbs. Thus, the introduction of LFGB (assuming it captures a 10% market share) has increased the price of all ground beef by \$.01/lb. and the quantity by 39.75 million lbs. over the mean ground beef price and quantity for the 1986–89 period. This represents a 1% increase in price and a .44% increase in quantity.[5]

Table 1. Sensitivity of Consumer and Producer Welfare Measures to the Estimates of the Total Response Demand and General Equilibrium Supply Elasticities

Total Response Demand Elasticity (η)[a]	General Equilibrium Supply Elasticity (ϵ_r)				
	.20	.40	.59	.80	1.00
	($ millions)				
−.55	42.0	66.4	81.6	93.5	101.8
	137.0	107.4	87.1	69.6	56.0
−.69	35.4	57.9	72.7	84.7	93.4
	143.6	115.9	96.0	78.4	64.4
−.86	29.7	50.1	64.2	76.1	84.9
	149.3	123.7	104.6	87.1	73.0
−1.02	25.8	44.4	57.8	69.4	78.2
	153.2	129.4	111.0	93.8	79.8
−1.15	23.4	40.7	53.5	64.8	73.5
	155.7	133.1	115.3	98.5	84.5

[a] The top number of each group represents increases in consumer surplus; the bottom number represents increases in total producer surplus.

Consumer and Producer Welfare Effects

The linear specification of the demand and supply curves illustrated in figure 1 simplifies the calculation of consumer and producer surplus. In addition, because the general equilibrium supply curve is being used, the producer surplus measure includes welfare effects for all producers (including livestock producers, input suppliers, livestock and food processors, and restauranteurs) on the supply side of the market (Just, Hueth, and Schmitz). The initial measure of consumer surplus is simply the area bounded by $P_0a_0E_0$, and the initial measure of producer surplus is the area $P_00q_0E_0$. The intercept parameters a_0, c_0, and q_0 are obtained from the above estimates of the demand and supply elasticities. At the initial equilibrium point, consumer surplus totals $7.21 billion, and producer surplus equals $8.74 billion.

After the introduction of LFGB, both the demand and supply curves shift and, consequently, consumer and producer surplus measures also change. It has been shown that the introduction of LFGB increases the weighted average leanness of ground beef products by one unit. Using the results of the hedonic model and assuming a parallel shift of the demand curve, the intercept (a_1) of the new demand curve (D_1) is $.0206 larger than the original intercept (a_0). Consumer surplus at the new equilibrium point (E_1) equals $7.27 billion (area $P_1a_1E_1$). The vertical shift of the supply curve caused by the introduction of LFGB has been estimated to be $.003. Thus, c_1 is $.003 larger than c_0. Producer surplus at the new equilibrium point equals $8.85 billion (area $P_10q_1E_1$). The change in consumer surplus totals $64.2 million, which is an .89% increase. The change in producer surplus totals $104.6 million and represents a 1.2% increase over its initial value.[6]

Alternative estimates of the retail supply and demand elasticities for ground beef affect equilibrium prices and quantities as well as the measures of changes in producer and consumer surplus. Table 1 presents welfare measures which result from allowing the supply elasticity (ϵ_r) to range from .20 to 1, and the demand elasticity (η) from −.55 to −1.15. For example, using the lower bound of the elasticity of the total response demand function (η = −.69) and a general equilibrium supply elasticity of .59 results in consumer and producer surplus changes of $72.7 million and $96 million, respectively.

Effects on Cattle Producers of the Introduction of Low-Fat Ground Beef

The introduction of LFGB increases the consumption of ground beef and the derived demand for nonfed cattle. Thus, LFGB will also affect cattle producers. Although lower-quality lean cuts of table cut beef can be redirected towards the production of LFGB, the demand for these products will continue to be met by meat packers. Therefore, additional cattle slaughter will be required to meet the increase in ground beef consumption.

The retail supply of ground beef is derived from the supply of nonfed cattle. Specifically, nonfed steer, nonfed heifer, cow, and bull producers are affected by the introduction of LFGB because they produce the raw material that, in general, is used to manufacture this new product (Cattle-Fax). The profit-maximizing decisions of cattle producers are the basis for the specification of the supply of nonfed cattle [equation (4)]. Following several previous studies (e.g., Azzam, Yanagida, and Linsenmeyer; Brester and Marsh; Marsh; Ospina and Shumway), equation (13) presents a partial adjustment model for the supply of nonfed cattle:

$$(13) \qquad NONFEDSL_t = \gamma_0 + \gamma_1 DPNONFED_t + \gamma_2 DPFEEDST_t + \gamma_4 DPHAY_t + \gamma_3 NONFEDSL_{t-1},$$

where *DPNONFED* is the deflated price of nonfed steers, nonfed heifers, cows, and bulls. The price of feeder steers is a proxy for the price of all feeder calves which are the primary output of the beef breeding herd. The price of hay is used as a proxy for the costs incurred by cow-calf producers of maintaining a breeding herd. The supply equation is estimated using annual data from 1962–89. A weighted average price for nonfed cattle cannot be calculated because an individual price series for each type of nonfed animal is not available. Therefore, the prices of commercial cows (*DPCOCOW*) in dollars/cwt. were obtained from various issues of *Livestock and Poultry Situation and Outlook Report* (USDA) and *Livestock and Meat Statistics* (USDA), and used as a proxy for the price of all nonfed steers, nonfed heifers, cows, and bulls.

Nonfed slaughter numbers and the price of commercial cows are probably jointly determined. Therefore, equation (13) is estimated using 2SLS:[7]

$$(14) \qquad NONFEDSL_t = \underset{(5.77)}{12{,}889} + \underset{(2.44)}{102{,}340} DPNONFED_t - \underset{(-3.43)}{100{,}140} DPFEEDST_t + \underset{(3.42)}{21{,}954} DPHAY_t + \underset{(2.70)}{.25} NONFEDSL_{t-1}$$

$$\bar{R}^2 = 0.87, \quad S_y = 930.26, \quad \bar{Y} = 11{,}809.18, \quad DF = 22, \quad \pi^2 = 3.20.$$

Each coefficient is significant at the .05 level and has the expected sign. The null hypothesis of the absence of serial correlation cannot be rejected at the .05 level. At the means, the own-price elasticity of supply of nonfed slaughter (ϵ_f) is 1.41.[8]

According to the Auburn University formulation, 95% lean LFGB is produced from boneless 90% lean manufacturing beef. On average, 65% of cow carcasses and 70% of bull carcasses produce boneless manufacturing beef. Of this, cow and bull carcasses can produce 45% and 96%, respectively, of manufacturing beef that is at least 90% lean (Cattle-Fax). Seventy-two percent of nonfed steer and heifer carcasses produce boneless manufacturing beef and approximately 60% of this product is at least 90% lean (Campbell). Applying these percentages to the average dressed weights of each type of nonfed carcass (over the 1986–89 period) results in the average amount of 90% lean boneless manufacturing beef obtained from each type of nonfed animal.

Recall that consumers demand an additional 39.75 million lbs. of ground beef because of the introduction to LFGB. If the various types of nonfed slaughter animals remain in similar proportions to those occurring during the 1986–89 period, then an additional 205,653 nonfed slaughter animals would be required to produce the needed 39.75 million lbs. of ground beef. Annual nonfed slaughter averaged 11,674,000 head during the 1986–89 period. Thus, the introduction of LFGB requires a 1.76% increase in nonfed slaughter.

Table 2. The Effect of the Market Share Captured by LFGB on Retail Ground Beef Price, Consumption, Consumer Surplus, Total Producer Surplus, and Cull Cow Prices

LFGB Market Share (%)	Retail Ground Beef Price ($/lb.)	Ground Beef Quantity (mil. lbs.)	Change in Consumer Surplus ($ mil.)	Change in Total Producer Surplus ($ mil.)	Change in Cull Cow Price ($/cwt.)
1	1.387	8,949	6.4	10.4	.06
5	1.393	8,965	32.1	52.2	.28
10	1.399	8,985	64.2	104.6	.56
20	1.413	9,025	128.7	209.5	1.12
30	1.426	9,065	193.5	314.8	1.69

The own-price elasticity of supply for nonfed animals (ϵ_f) was estimated to be 1.41. Therefore, a 1.25% (i.e., 1.76%/1.41) increase in the price of nonfed animals will be necessary to generate the required supply response. The average nominal price of commercial cows (used as a proxy for the price of nonfed slaughter animals) over the 1986–89 period was $45/cwt. Thus, the introduction of LFGB will increase the average live weight value of commercial cows by $.56/cwt.

The introduction of LFGB increases both the price and quantity supplied of nonfed slaughter cattle and the producer surplus of nonfed cattle products. Producer surplus at the farm level increases by $63.2 million, which represents a 3.55% change.

Assuming a total response demand elasticity of −.86 and a general equilibrium supply elasticity of .59, the increase in producer surplus for all producers on the supply side of the market is $104.6 million (table 1). Subtracting the producer surplus of cattle producers ($63.2 million) from the total measure of producer surplus results in a measure of welfare that accrues to meat processors and suppliers of other marketing inputs exclusive of cattle producers. This difference equals $41.4 million. Therefore, 60% of the increase in producer surplus caused by the introduction of LFGB accrues to cattle producers.

Sensitivity of Results to the Market Share Captured by Low-Fat Ground Beef

Alternative assumptions regarding the share of the ground beef market garnered by LFGB affect consumer and producer surplus measures as well as the equilibrium price and quantity of ground beef. Table 2 presents market and welfare results for various LFGB market shares using the elasticities $\eta = -.86$ and $\epsilon_r = .59$. For example, if LFGB gains a 20% share of the ground beef market, the new retail equilibrium price and quantity would be $1.41/lb. and 9,025 million lbs. Consumer and total producer surplus measures would increase by 1.79% and 2.4% ($128.7 million and $209.5 million, respectively), and the price of commercial cows would increase by $1.13/cwt. Conversely, the market and welfare effects are much smaller if LFGB captures only a small share of the ground beef market.

Conclusions

The ultimate effects of the introduction of low-fat ground beef upon consumers, processors, and cattle producers will be determined primarily by its acceptance by consumers. A hedonic model shows that each unitary increase in the leanness of ground beef carries a $.0206/lb. price premium. Low-fat ground beef is leaner than other ground beef products but is designed to be as palatable as 80% lean ground beef. This new product costs approximately $.03/lb. more to produce than 90% lean ground beef because of additional labor and ingredient requirements.

If LFGB garners a 10% share of the ground beef market, the equilibrium retail price of aggregate ground beef products will increase by $.01/lb., and the equilibrium quantity will increase by 39.75 million lbs. Consumer and producer surplus measures will increase by .89% and 1.2%. These changes are relatively insensitive to retail demand and supply elasticity estimates.

Primarily nonfed cattle are used to produce LFGB. The increased equilibrium quantity at the retail level will increase the annual derived demand for nonfed slaughter cattle by 205,653 head. This represents a 1.76% increase in nonfed slaughter and requires a 1.25% increase in the price of nonfed cattle to generate the supply response. Consequently, the introduction of LFGB will increase the average live weight value of commercial cows by $.56/cwt. Producer surplus at the cattle producer level will increase by 3.55%. All of these effects are magnified as the market share captured by LFGB increases.

Finally, beef by-product markets also will be affected by the introduction of LFGB. The increase in cattle slaughter numbers and the emphasis on additional trimming will increase the supply of many by-products, especially tallow.

[*Received September 1992; final revision received May 1993.*]

Notes

[1] Imports are another component of ground beef supply. However, beef imports are restricted by the U.S. Beef Import Act of 1979 (Simpson). During the past five years, beef imports have been near the maximum allowed by current import quota restrictions. Thus, in the absence of exogenous changes in the quotas, imports will not be a viable source for the raw material needed to produce LFGB.

[2] Recall that some very lean (90–94% lean) ground beef products are currently produced. However, as indicated by the small market share, most consumers do not find this product palatable.

[3] The instrumental variables used in the model are the January 1 inventory of cattle, the deflated price of corn, and all of the exogenous right-hand-side variables. Alternative specifications of equation (11) were considered. For example, the appropriateness of the linear functional form was examined by estimating the supply function using a double-log form. The supply elasticity was unaffected by this alternative specification.

[4] The parameter estimates for β_0 and β_1 cannot be directly used for the slope and intercept estimates in figure 1 because equation (11) is estimated in a quantity-dependent form.

[5] It is assumed that the own-price elasticities of demand and supply are the same at E_0 and E_1 in figure 1. The assumption seems reasonable given the relatively small price and quantity changes.

[6] Although substitution between fat and other products (i.e., carrageenan) is considered, it is assumed that fixed input proportions exist between the raw farm input (cattle) and other marketing inputs. The relaxation of this assumption would reduce the general equilibrium supply elasticity, and subsequently, the welfare measures (Wohlgenant).

[7] The instrumental variables used in the model are the deflated price of feeder steers, the deflated price of hay, the deflated price of corn, the January 1 inventory of cattle, and the lagged dependent variable.

[8] Schroeter estimates the own-price elasticity of supply for all cattle in the U.S. to be 1.69. Alternative specifications of equation (13) were considered. Similar elasticities were found by estimating the equation in a double-log form. Linear and nonlinear trend variables were considered as explanatory variables, but were not significant.

References

Azzam, A. M., J. F. Yanagida, and D. Linsenmeyer. "A Linked Econometric Model of the Livestock-Feed Sectors in Nebraska and the Rest of the United States." *N. Cent. J. Agr. Econ.* 9(1987):247–58.

Brester, G. W., and J. M. Marsh. "A Statistical Model of the Primary and Derived Market Levels in the U.S. Beef Industry." *West. J. Agr. Econ.* 8(1983):34–49.

Brester, G. W., and M. K. Wohlgenant. "Estimating Interrelated Demands for Meats Using New Measures for Ground and Table Cut Beef." *Amer. J. Agr. Econ.* 73(1991):1182–94.

Buse, R. C. "Total Elasticities—A Predictive Device." *J. Farm Econ.* 40(1958):881–91.

Campbell, B. Ph.D. candidate, Dept. Animal Science and Industry, Kansas State University. Personal communication, January 1991.

Cattle-Fax. "An Economic Analysis of Low-Fat Ground Beef." CF Mimeo Rep., Englewood CO, September 1991.

Council of Economic Advisors. *Economic Indicators.* Washington DC: Government Printing Office. Various issues.

Dunkelberger, J. E., D. H. Summerford, D. L. Huffman, and W. R. Egbert. "Consumer Responses to a New

Lean Ground Beef Product: Results from a Home-Use Comparative Test of AU Lean." Tech. Bull. No. 612, Alabama Agr. Exp. Sta., Auburn University, 1991.
Godfrey, L. G. "Testing for Serial Correlation in Dynamic Simultaneous Equation Models." *Econometrica* 44(1976):1077–84.
Harp, H. H. "The Food Marketing Cost Index: A New Measure for Analyzing Food Price Changes." ESCS Tech. Bull. No. 1633, U.S. Department of Agriculture, Washington DC, August 1980.
Just, R. E., D. L. Hueth, and A. Schmitz. *Applied Welfare Economics and Public Policy.* Englewood Cliffs NJ: Prentice-Hall, Inc., 1982.
Lemieux, C. M., and M. K. Wohlgenant. "Ex Ante Evaluation of the Economic Impact of Agricultural Biotechnology: The Case of Porcine Somatotropin." *Amer. J. Agr. Econ.* 71(1989):903–14.
"LFGB Enters the Industry's War on Fat." *Drovers J.* 118,12(December 1990):14–15.
Marsh, J. M. "The Effects of the Dairy Termination Program on Live Cattle and Wholesale Beef Prices." *Amer. J. Agr. Econ.* 70(1988):919–28.
"The Men Behind McLean." *Beef Today* 7,9(October 1991):48–50.
Menkhaus, D. J., G. D. Whipple, and R. A. Field. "Some Consumers Will Pay Extra for Lean Beef." *Choices* (2nd Quarter, 1988):28–29.
Miller Meats. Personal communication with Bob Moran, product manager, Chino CA, August 1991.
National Live Stock and Meat Board. "Market Potential for Low-Fat Ground Beef." Pub. No. FS/M 006, Chicago IL, 1991.
Ospina, E., and C. R. Shumway. "Disaggregated Analysis of Short-Run Beef Supply Response." *West. J. Agr. Econ.* 4(1979):44–59.
Pinkerton, W. F. *Low-Fat Ground Beef: A Chronology of Technological Development.* Chicago IL: National Live Stock and Meat Board, 1991.
Rose, R. N. "Supply Shifts and Research Benefits: Comment." *Amer. J. Agr. Econ.* 62(1980):834–37.
SAS Institute, Inc. *SAS/ETS User's Guide, Version 6,* 1st ed. Cary NC: SAS Institute, Inc., 1988.
Schroeter, J. R. "Estimating the Degree of Market Power in the Beef Packing Industry." *Rev. Econ. and Statis.* 70(1988):158–62.
Simpson, J. R. "The Countercyclical Aspects of the U.S. Import Act of 1979." *Amer. J. Agr. Econ.* 64(1982): 243–48.
Thurman, W. N., and M. K. Wohlgenant. "Consistent Estimation of General Equilibrium Welfare Effects." *Amer. J. Agr. Econ.* 71(1989):1041–45.
Unnevehr, L. J. "Consumer Demand for Rice Grain Quality and Returns to Research for Quality Improvement in Southeast Asia." *Amer. J. Agr. Econ.* 68(1986):634–41.
U.S. Department of Agriculture. *Feed Situation and Outlook Report.* Washington DC: Economic Research Service. Various issues, 1970–91.
———. *Food Consumption, Prices, and Expenditures.* Washington DC: Government Printing Office, 1980 and 1989.
———. *Livestock and Meat Statistics.* Washington DC: Economic Research Service, 1983 and 1988.
———. *Livestock, Meat, and Wool Market News.* Washington DC: Agricultural Marketing Service. Various issues, 1986–90.
———. *Livestock and Poultry Situation and Outlook Report* (formerly *Livestock and Meat Situation.*) Washington DC: Economic Research Service. Various issues, 1970–89.
———. *Livestock Slaughter.* Washington DC: National Agricultural Statistics Service. Various issues, 1984–90.
U.S. Department of Commerce. *Survey of Current Business.* Washington DC: Bureau of Economic Analysis. Various issues, 1986–92.
Western Livestock Marketing Information Project (now renamed the Livestock Marketing Information Center). Table 1.123, 3 February 1988, and personal communication, Denver CO.
White, H. "A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity." *Econometrica* 48(1980):817–38.
Wohlgenant, M. K. "Demand for Farm Output in a Complete System of Demand Functions." *Amer. J. Agr. Econ.* 71(1989):241–52.