Agricultural Economics, 8 (1992) 45–56
Elsevier Science Publishers B.V., Amsterdam

Willingness to pay for pST-treated pork

Abdelmoneim H. Elnagheeb [a], Wojciech J. Florkowski [a], Chung-Liang Huang [a] and Catherine Halbrendt [b]

[a] *Department of Agricultural Economics, University of Georgia, Griffin, GA, USA*
[b] *Department of Food and Resource Economics, University of Delaware, Newark, DE, USA*

(Accepted 13 February 1992)

ABSTRACT

Elnagheeb, A.H., Florkowski, W.J., Huang, C.-L. and Halbrendt, C., 1992. Willingness to pay for pST-treated pork. *Agric. Econ.,* 8: 45–56.

The progress in porcine somatotropin (pST) application justified an assessment of consumer acceptance of pST-treated pork. A survey of the Atlanta metropolitan area, USA, collected information about consumer attitudes toward lean pork produced with biotechnologically developed pST. A qualitative dependent variable model was used to identify socioeconomic consumer characteristics influencing the willingness to pay for lean pork. The model was modified to account for the selectivity bias of the sample data.

Results indicate that frequent pork consumers were willing to pay more for lean pork produced using pST in contrast to respondents who frequently ate beef, were older, and had relatively high income.

Probabilities associated with the willingness to pay a specific premium were calculated. In general, the average respondent was willing to pay an additional 18¢ per kg of lean pork produced using pST.

Studies concerning health impacts of fatty acid consumption have linked saturated fats to high levels of blood cholesterol and increased risk of heart and heart-related diseases. Red meats, beef, and pork, are considered high in saturated fats and cholesterol when compared to poultry or fish. The importance of nutrition and health influences food choices (National Research Council, 1988). Many consumers were interested in leaner pork

Correspondence to: W.J. Florkowski, Department of Agricultural Economics, Georgia Station, Griffin, GA 30223-1797, USA.

consumption when such an option was presented to them in a USDA survey (Lemieux and Wohlgenant, 1989).

Traditionally, leaner pork production has been based on selective breeding over an extended period of time (Mersmann, 1987). An alternative technology has been developed through bioengineering microorganisms enabling them to produce large quantities of porcine somatotropin naturally occurring in swine. Porcine somatotropin (pST), a growth hormone, stimulates the growth rate of hogs and reduces fat deposition (Boyd et al., 1986). PST is undergoing tests on commercial hog farms in Iowa (Hayenga, 1990) and is expected to be made available to farmers if approved by the Food and Drug Administration (FDA).

The progress in commercial application of pST and its pending FDA approval in hog production underlaid this assessment of consumer acceptance of pST-treated pork. Such an assessment seemed appropriate in view of the negative publicity and consumer reaction in case of bovine somatotropin (Douthitt, 1990), which stimulates milk production in cows. Included in the consumer pST acceptance study is the issue of consumer willingness to pay (WTP) for leaner pork produced using pST. This study was designated to ascertain consumer attitudes towards lean pork produced with biotechnologically obtained pST. A qualitative dependent variable model has been applied to identify important socioeconomic consumer characteristics influencing the WTP for lean pork following an application of a selectivity bias test on sample data.

THE MODEL

Each surveyed respondent was offered to select a single category from a set of ordered price premiums for leaner pork. Each premium represented the amount a respondent would be willing to pay per pound of leaner pork above the actual price. Facing such an ordered set of J alternatives ($j = 1, 2, \ldots, J$), a respondent was assumed to select a utility-maximizing alternative. The respondent's utility was assumed to be represented by a well-behaved preference function, U (Trost and Lee, 1984). The maximum utility attained by choosing alternative j, U_{ij}, was postulated to be a linear function of exogenous variables:

$$U_{ij} = X_i'\beta + e_{ij} \tag{1}$$

where X_i was a $K \times 1$ vector of exogenous variables, β is a $K \times 1$ vector of unknown parameters to be estimated, and e_{ij} was a random error assumed to be identically normally distributed with zero mean and unit variance.

Theoretically, the respondent would compare U_{ij} for $j = 1, \ldots, J$, and select the utility-maximizing alternative. Let P_{ih} represent the probability that an alternative h would be chosen. Then, the individual would choose an alternative, say, k, such that $P_{ik} > P_{ij} \forall_j$, $j \neq k$, and where:

$$P_{ik} = Pr[U_{ik} > \max(U_{i1}, U_{i2}, \ldots, U_{ik-1}, U_{ik+1}, \ldots, U_{iJ})] \tag{2}$$

Although U_{ij} is not observable, the outcome of the respondent's decision process is reflected in the selection of a certain price premium. However, the survey about pST use in pork production was conducted among randomly selected consumers and could include pork consumers as well as persons who do not consume pork. Respondents who indicated they did not consume pork would not be willing to pay any positive amount for leaner pork. The question of WTP should be addressed to pork eaters only. A model estimation based on data limited to respondents consuming pork may lead to a selectivity bias if the subsample is not random. Estimated model parameters would be inconsistent. The self-selectivity bias within the sample has to be eliminated to assure randomness of responses.

In order to correct for a potential bias, we apply a criterion function introduced by Heckman (1979) for an analogous problem. Let $T_i = 1$ if the ith respondent consumes pork, zero otherwise. Also:

$$T_i^* = Z_i\alpha + v_i \tag{3}$$

where T_i^* is the unobservable utility derived by the ith respondent from eating pork, Z_i is a set of exogenous variables, and $v_i \approx N(0, 1)$. The observed T_i recorded in returned questionnaires allowed to re-specify equation (1) as:

$$\mathrm{E}[U_i|X_i, T_i^* \geqslant 0] = X_i\beta + \mathrm{E}[e_i|X_i, T_i^* \geqslant 0] \tag{4}$$

Assuming e and v are bivariate normally distributed with correlation coefficient ρ, then:

$$\mathrm{E}[e_i|X_i, T_i^* \geqslant 0] = \mathrm{E}[e_i|X_i, v_i \geqslant -Z_i\alpha] = \rho\lambda_i$$

where $\lambda_i = f(-Z_i\alpha)/F(Z_i\alpha)$ is a ratio of the density and the cumulative distribution function for a standard normal variable. The equation for the subsample of respondents eating pork is given by:

$$U_{ij} = X_i\beta + \rho\lambda_i + \varepsilon_{ij} \tag{5}$$

Equation (5) can be estimated using the ordered probit approach if a consistent estimate of λ_i is obtained. Following Heckman (1979), a consistent λ_i is obtained by estimating equation (3) using ordinary probit approach and all sample observations to compute consistent estimates of α. Estimates $\hat{\alpha}$ can then be used to obtain consistent estimates of λ_i. Equation (5) can then be estimated using the subsample containing respondents eating pork as an ordered probit model by replacing λ_i with $\hat{\lambda}_i$.

A test of selectivity bias is equivalent to a t-test of the null hypothesis that ρ equal zero. This procedure was applied to estimate the empirical model.

For the practical purpose of marketing pST-treated pork it is essential to know the probability that a respondent falls in one of the offered price premium categories. Such a probability is given by:

$$P_{ij} = \Pr(\text{WTP}_i = C_j) = \Phi(\mu_j - X_i\beta - \rho\lambda_i) - \Phi(\mu_{j-1} - X_i\beta - \rho\lambda_i) \tag{6}$$

where Φ is the standard normal cumulative distribution function, C_j denotes jth price premium a respondent would be willing to pay, and μ_j is an unknown threshold to be estimated such that $\mu_0 = -\infty$, $\mu_6 = +\infty$, and $\mu_0 \leqslant \mu_1 \leqslant \mu_2 \leqslant \ldots \leqslant \mu_6$.

For estimation purposes, let a binary variable S_{ij} take the value of one if the ith respondent chooses to pay C_j, zero otherwise; hence, $P_{ij} = \Pr(S_{ij} = 1)$. The likelihood function for (6) is:

$$L(\beta, \mu) = \prod_{i=1}^{n} \prod_{j=1}^{J} (P_{ij})^{S_{ij}} \tag{7}$$

and the log likelihood function is given by:

$$L^* = \log\ L(\beta, \mu) = \sum_{i=1}^{n} \sum_{j=1}^{J} S_{ij}\ \log(P_{ij}) \tag{8}$$

For the identification of the model in equation (6), we assume, without loss of generality, that $\mu_1 = 0$ (McKelvey and Zavoina, 1975). The model parameters (β, ρ, $\mu_2, \ldots, \mu_5$) can be estimated by maximization of equation (8) using the maximum likelihood method. Estimates obtained using maximum likelihood are consistent and asymptotically efficient (Maddala, 1983).

SAMPLE DATA

For the purpose of this study, a random sample was drawn from residents of the Atlanta metropolitan area. A roughly equal number of respondents was selected from each of the three income classifications by Donnelly, Inc. The income classifications were specified as individuals with annual income of (1) \$15,000 or less, (2) \$15,001–\$35,000, and (3) above \$35,000.

Survey questions were drawn from several categories, one including questions on the frequency of eating different kinds of meat and reasons for consuming meat; other questions asked directly for opinions about the use of pST. Questions probing respondents' opinions about WTP for pST-treated pork allowed for a number of categorized responses. Specifically, a surveyed consumer could choose to pay 0, 5, 10, 15, 25, or 50 cents above the current price per pound of the leaner pork. The last category of questions collected information about respondents' socioeconomic characteristics, such as age, sex, marital status and education level.

Questionnaires were mailed to 1591 individuals in June 1988. A follow-up mailing to those who did not respond after the first mailing was conducted in September 1988. The two mailings resulted in 495 returned usable questionnaires. The response rate was 31.1%.

ESTIMATION RESULTS AND WILLINGNESS TO PAY

Table 1 presents definitions and descriptive statistics of the explanatory variables (X and Z) expected to influence the respondent's willingness to pay for pST-treated pork and respondent's decision to eat pork or not. These variables include an index of income, socioeconomic characteristics of the respondent, the respondent's attitudes towards pST-treated pork, and variables describing the respondent's consumption of beef and fish.

The estimates of the coefficients of the probit model of equation (3) are presented in Table 2. The chi-square test rejected the null hypothesis that all coefficients on the explanatory variables (Z) are simultaneously equal to zero. The probability to eat pork was found to increase with the size of the household and age. The probability is also higher for whites than blacks, and for meat 'lovers' than non-meat 'lovers' as well as the excluded category, those who responded 'don't know'. The consumer's concerns about the use of vitamins, additives, hormones, and antibiotics in meat production have no influence on the respondent's decision on pork consumption. Although the income coefficient is not significantly different from zero, its negative sign indicates that the probability to eat pork decreases with income.

The empirical ordered probit model of equation (5) was estimated using observations only on the subsample of pork eaters after correcting for selectivity bias. Out of 426 usable questionnaires, 361 (85%) respondents do eat pork. The results of estimating equation (5) are presented in Table 2. A t-value for ρ of 1.031 indicated that selectivity bias was not significant at the 10% level. Therefore, the subsample limited to pork-eating respondents remained a random sample. The chi-square test allowed the rejection of the null hypothesis that all coefficients of the explanatory variables (X) are simultaneously equal to zero.

Respondents who indicated readiness to eat more pork if it becomes leaner were found to be willing to pay more for pST-treated pork than those who were less likely to eat more leaner pork. The latter group was

TABLE 1

Definitions and descriptive statistics of variables used in the analysis

Variable name	Description	Mean
Income	1 if annual income is \$15,000 or less 2 if annual income is \$15,001-\$35,000 3 if annual income is above \$35,000	2.283 [a]
Household size	The number of individuals in household	2.357
White	1 if white, 0 otherwise	0.795
Female	1 if female, 0 otherwise	0.485
Age	Respondent's age in years	47.44
Beef 'lover'	1 if respondent eats beef seven times or more a week, 0 otherwise	0.036
Fish 'lover'	1 if respondent eats fish seven times or more a week, 0 otherwise	0.044
Most likely eat more	1 if respondent will most likely eat more pork if it becomes leaner, 0 otherwise	0.285
Less likely eat more	1 if respondent will less likely eat more pork if it becomes leaner, 0 otherwise	0.122
Eat no pST pork	1 if respondent will most likely eat pork produced without use of pST, 0 otherwise	0.125
Eat pST pork	1 if respondent will less likely eat pork produced without use of pST, 0 otherwise	0.166
No change	1 if respondent's pork consumption will not change, 0 otherwise	0.352
Meat 'lover'	1 if respondent agreed that a main meal must include meat to satisfy his appetite, 0 otherwise	0.566
Not meat 'lover'	1 if respondent disagreed with "a main meal must include meat to satisfy my appetite", 0 otherwise	0.427
Concerned	1 if respondent is concerned about use of vitamins, additives, hormones, and antibiotics in meat production, 0 otherwise	0.887
Not Concerned	1 if respondent is not concerned about use of vitamins, additives, hormones, and antibiotics in meat production, 0 otherwise	0.296

[a] Income was classified into three categories as shown. Using midpoints of the three categories the average income of a respondent was \$31,177. The midpoint of the last category was assumed to correspond to the distance of the midpoint in the second category from its boundaries.

also found to be willing to pay less for pST-treated pork than the excluded category of those who were uncertain about their future pork consumption. Furthermore, results suggest that leaner pork will still compete with beef, another red meat. Respondents who eat beef at least seven times a week

TABLE 2

Ordered probit results of willingness-to-pay model

Variable name	Equation (3) coefficient (t-value)		Equation (5) coefficient (t-value)	
Meat 'lover'	1.05769 *	(1.676)		
Not meat 'lover'	0.286628	(0.462)		
Concerned	−0.286266	(−1.019)		
Not concerned	0.205415	(0.987)		
Income	−0.065980	(−0.530)	−0.14103 *	(−1.695)
Household size	0.173149 **	(1.999)	−0.0362143	(−0.608)
White	0.319929	(1.463)	−0.0150957	(−0.086)
Female	0.132364	(0.681)	0.0130009	(0.106)
Age	0.009722	(1.564)	−0.0114223 **	(−2.588)
Constant	−0.408253	(−0.486)	1.174170 **	(3.093)
Beef 'lover'			−0.886380 *	(−1.911)
Fish 'lover'			−0.39573	(−0.108)
Most likely eat more			0.595545 **	(4.014)
Less likely eat more			−0.332195	(−1.456)
Eat no pST pork			−0.545634 **	(−2.159)
Eat pST pork			0.0780066	(0.409)
No change			−0.0165134	(−0.121)
μ_2			0.468840 **	(8.029)
μ_3			1.00532 **	(11.069)
μ_4			1.40776 **	(11.850)
μ_5			1.96695 **	(11.462)
ρ			−0.375016	(1.031)
χ^2	35.936 **		61.963 **	

* and ** indicate significance at the 10% and 5% level, respectively.

were found to be willing to pay less for leaner pork than those who consumed beef less than seven times a week.

The use of food additives and growth hormones has triggered concerns of many consumers. Hence, the mere use of pST, regardless of its effect on pork, may cause some consumers to reduce pork consumption. Respondents who stated that they would most likely consume pork produced without pST were found to be willing to pay less than those who were most likely to eat pST-treated pork. The estimated coefficient on respondent's age is negative and statistically significant, indicating that willingness to pay for pST-treated pork decreases with age. A plausible explanation is that older consumers often live off a fixed income and paying a premium would represent an additional expense. Income carries also a negative and statistically significant coefficient indicating that as income increases consumers become less willing to pay a premium for pST-treated pork. This result indicates that as income increases people shift to other types of meat. That is, pork may not be a normal good. Moreover, respondents with higher incomes frequently are better educated and may require more information about wholesomeness of pST-treated pork prior to a purchase.

Probabilities associated with the willingness to pay a specific premium are a function of the estimated parameters and were calculated using equation (6). The estimates of Table 2 were used to calculate the expected willingness to pay (EWTP) for leaner pork, as follows:

$$\text{EWTP} = \sum_{j=1}^{6} P_j C_j \tag{9}$$

where P_j is obtained by evaluating $\Pr(\text{WTP}_i = C_j)$ of equation (6) at the means, $\bar{X}$ and $\bar{\lambda}$. An alternative measure of the EWTP is to average the expected willingness to pay of all individuals using the formula:

$$\text{EWTP} = (1/n) \sum_i \sum_j P_{ij} C_j = \sum_j \left[(1/n) \sum_i P_{ij} \right] C_j = \sum_j \bar{P}_j C_j \qquad i = 1, \ldots, n \qquad j = 1, \ldots, J \tag{10}$$

where $\bar{P}_j$ is the average, across respondents, of probabilities of willingness to pay C_j, and P_{ij} is obtained by evaluating equation (6) at the actual observation for the ith respondent. Using equations (9) and (10), the calculated EWTP are 16.93 and 18.50 cents per kg, respectively. Table 3 also presents the values of P_j and $\bar{P}_j$ as well as the sample frequencies. Values of $\bar{P}_j$ are closer to the sample frequencies than those of P_j. Hence, the EWTP calculated from equation (10) is closer to the sample EWTP, while that calculated from equation (9) is marginally lower than the sample EWTP.

TABLE 3

Distribution of respondents' willingness to pay for lean pork treated with pST

C_j	Observed frequencies, f_j (%)	Model results at means, P_j [a] (%)	Model results – individual, $\bar{P}_j$ [a] (%)
\$.00	43.8	43.6	44.1
.05	16.9	17.8	16.8
.10	17.2	18.8	16.9
.15	9.7	9.2	9.4
.25	8.0	7.1	7.9
.50	4.4	3.5	5.0
EWTP (¢/kg)	18.10	16.93	18.50

[a] See equations (9) and (10) for the definitions of P_j and $\bar{P}_j$.

The approaches of equations (9) and (10), however, may underestimate the EWTP. By choosing to pay C_j a respondent may be willing to pay C_j or more, but less than C_{j+1}, where C_{j+1} is the next higher value. Another approach to estimate both the median and mean WTP is presented below.

In order to estimate the probability of willingness to pay any amount ranging from zero to 50 cents, we estimated the cumulative probability, CP (Table 4, column 3) as a function of bids, C (Table 4, column 1):

$$\mathrm{CP}_j = a \exp\left(\beta C_j + \gamma C_j^2\right) U_j \tag{11}$$

where a, β, and γ are parameters to be estimated, and U_j is a random error with a zero mean. THis functional form is chosen based on the data in Table 4 and β is expected to be negative, while γ is expected to be positive. Taking the logarithm of (11) will result in a linear function that can be estimated by ordinary least squares (OLS). Preliminary estimation of equation (11) with γ equal to zero was changed by the introduction of C_j^2 improving statistical results. Also, in equation (11), the value of a equal 1 (or $\log(a) = 0$) was expected because at $C_j = 0$, CP_j is equal to one. That expectation was confirmed by the OLS results where the constant term did not differ from zero at the significance level lower than 20%. Estimation results of equation (11), without the constant term, are presented below:

$$\begin{aligned} \ln \mathrm{CP}_j = &\ -0.108\,88\, C_j + 0.000\,931\, C_j^2 \\ &\ (-30.406) \qquad (11.419) \qquad R^2 = 0.9985 \end{aligned} \tag{12}$$

where $\ln \mathrm{CP}_j$ is the log of CP_j, R^2 is the correlation between the observed CP_j and CP_j as predicted by the model $\widehat{\mathrm{CP}}_j = \exp(\ln \mathrm{CP}_j)$, and t-ratios are reported in parentheses. Values of $\widehat{\mathrm{CP}}_j$ are reported in the last column of

TABLE 4

Observed and predicted frequencies of willingness to pay

Bid, C_j (¢)	Observed relative frequency, f_j	Cumulative frequence [a], CP_j	Predicted [b] CP_j ($\widehat{\mathrm{CP}}_j$)
0	0.438	1.000	1.000
5	0.169	0.562	0.594
10	0.172	0.393	0.369
15	0.097	0.221	0.241
25	0.080	0.124	0.118
50	0.044	0.044	0.044

[a] Cumulative frequency represents the probability of paying C_j or more: $\mathrm{CP}_j = \Pr(\mathrm{WTP} \geqslant C_j)$.
[b] Using equation (12).

Table 4. Equation (12) was used to estimate the median (MWTP) and mean (EWTP) willingness to pay. The median is the value of C such that:

$$\exp(-0.108\,88\,C + 0.000\,931\,C^2) = 0.5$$

or

$$0.000\,931\,C^2 - 0.108\,88\,C + 0.693\,15 = 0 \tag{13}$$

Equation (13) is quadratic in C and the solution yields two values for C: 6.76 or 110.19 cents. Given the data in Table 4, it is obvious that the median should be 6.76¢ per pound or 14.90¢ per kg.

The mean WTP (EWTP) is:

$$\text{EWTP} = \int_0^{50} \widehat{\text{CP}}(C)\ \mathrm{d}C = \int_0^{50} \exp(-0.108\,88\,C + 0.000\,931\,C^2)\ \mathrm{d}C \tag{14}$$

where the upper limit of integration is truncated at 50 cents, representing the maximum bid in the survey (Bishop and Heberlein, 1979).

Equation (14) can be approximated by (Spiegel, 1968, p. 94):

$$\text{EWTP} = \Delta C\left[\lim_{n\to\infty} \sum_{i=1}^{n} \widehat{\text{CP}}((i-1)\ \Delta C)\right] \tag{15}$$

where

$$\Delta C = \frac{50-0}{n} = \frac{50}{n}$$

In this study, n varied from 100 to 1000, but results remained fairly stable. For $n = 100$, equation (15) results in EWTP of 25.09 cents per kg, while for $n = 1000$, the EWTP is about 24.60 cents per kg, a difference of less than 3%. The values are higher than the value given by equations (9) and (10), as expected. With the difference between the mean and median WTP being large (mean WTP is about 1.7 times the median), we suggest using the median as an estimate of WTP for improvement in pork quality because the median is more robust to errors and outliers than the mean (Hanemann, 1984).

IMPLICATIONS

Survey results indicated that over 50% of respondents who consumed pork would be willing to pay a premium for pST-treated pork. Results indicated that, on the average, a consumer participating in the survey would be willing to pay an additional 25¢ per kg of lean pork produced using pST. However, the evaluation of the WTP at the median indicated that consumers may only be willing to pay as much as 15 cents more per kg of pST-treated pork.

The average premium must be sufficient to offset the cost of pST application. Currently, pST is injected daily into treated hogs, raising labor costs. However, given the repeated results of pST use suggesting a lower feeding cost because of improved feed conversion and faster growth rates, pST may immediately appeal to hog farmers. Fast adoption of new technology may increase pork supply and, at least in the short term, cause pork prices to decline.

Although older consumers were less likely to pay a premium for leaner pST-treated pork, they also represented a group that limits its overall red meat consumption. Another finding was that higher income respondents also were less likely to pay a premium for leaner pork. Reasons could include different consumption habits or reflect greater concerns about food safety than consumers with lower incomes. Additional analysis about consumer attitudes towards pST-treated pork is warranted in order to further explain differences in the WTP.

Results of the study indicated that lean pST-treated pork will not be a substitute for respondents who revealed high preference for beef. Apparently those respondents did not find the leanness of pork to cause a change in their consumption habits.

Consumers' concern about food safety needs to be addressed prior to the introduction of the pST-treated pork on the market. An educational campaign based on thoroughly verified information about pST impact on hogs, pork, and consumption of pST-treated pork could enhance consumer acceptance. Differences between consumer attitudes towards bovine somatotropin and porcine somatotropin suggest that consumers can be selective in the acceptance of a bioengineered food product. For example, Czechoslovakia and the former Soviet Union approved the use of bST on commercial dairy farms without a demonstration of consumers' opposition. A consumer study prior to commercial introduction of a new product is, however, necessary because of possible adverse public reaction caused by fear and insufficient knowledge about a product. The application of bioengineering techniques can enhance the quality and efficiency of food production only if consumers recognize such technologies as scientifically sound and nutritionally wholesome.

REFERENCES

Bishop, R.C. and Heberlein, T.A., 1979. Measuring values of extramarket goods: Are indirect measures biased? Am. J. Agric. Econ., 61: 926–930.

Boyd, R.D., Bauman, D.E., Beerman, D.H., DeNeergard, A.E., Souze, L. and Kuntz, H.T.,

1986. Porcine somatotropin: Dose titration for maximum growth rate, feed efficiency, and lean deposition of swine. Proc. Cornell Nutrition Conf., pp. 24–28.

Douthitt, R., 1990. Wisconsin consumers' attitudes towards bovine somatotropin (ST) and dairy product labeling. Department of Consumer Science, University of Wisconsin, Madison, WI.

Hanemann, W.M., 1984. Welfare evaluations in contingent valuation experiments with discrete responses. Am. J. Agric. Econ., 66: 332–341.

Hayenga, M., 1990. A look at potential pST impacts. Paper presented at the NCR-142 Meeting, 1–2 October 1990, San Antonio, TX.

Heckman, J., 1979. Sample selection bias as a specification error. Econometrica, 46: 153–161.

Lemieux, C.M. and Wohlgenant, M.K., 1989. Consumer acceptance and demand for lean pork. Paper presented at organized symposium at AAEA Annual Meeting, 31 July–3 August 1989, Baton Rouge, LA.

McKelvey, R.D. and Zavoina, W., 1975. A statistical model for the analysis of ordinal level dependent variables. J. Math. Sociol., 4: 103–120.

Maddala, G.S., 1983. Limited-dependent and Qualitative Variables in Econometrics. Cambridge University Press, New York, 401 pp.

Mersmann, H.J., 1987. Primer on beta adrenergic agonists and their effect on the biology of swine. In: The Repartitioning Revolution: Impact on Somatotropin and Beta Adrenergic Agonists on Future Pork Production. University of Illinois Pork Industry Conf. Proc., 10–11 December 1987.

National Research Council, 1988. Designing Foods. National Academy Press, Washington, DC, 367 pp.

Spiegel, M.R., 1968. Mathematical Handbook of Formulas and Tables. McGraw-Hill, New York, 271 pp.

Trost, R.P. and Lee, L.F., 1984. Technical training and earnings: a polychotomous choice model with selectivity. Rev. Econ. Stat., 56: 151–156.