ECONOMIC ANALYSIS OF MEAT PROMOTION

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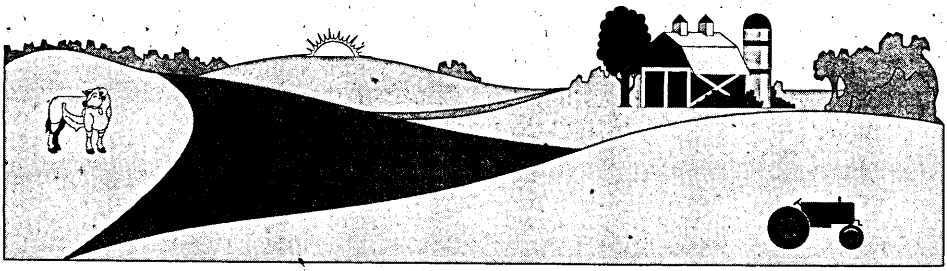

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DIRECT AND SPILLOVER EFFECTS OF INCREASED U.S. BEEF PROMOTION

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Meat markets are interrelated through consumer preferences at retail and competition for common resources at the farm level. Thus, if one industry, say beef, intensifies its marketing efforts, it has consequences for the related markets (e.g., pork and poultry). The purpose of the research reported in this paper is to elucidate these interrelationships by quantifying the effects of an isolated increase in beef promotion on prices, quantities, and producer surpluses in the beef, pork, and poultry markets.

We first develop a Muth-type equilibrium displacement model of the U.S. beef sector that takes into account supply response, cross-commodity substitution, and advertising spillover. The structural model differs from similar models (e.g., Alston, Chalfant and Piggott) in that a distinction is made between retail markets, where advertising occurs, and farm-level markets, where measurements of producer returns are taken.[1]

We then estimate consumer demand relationships for U.S. meats, including fish, using a Rotterdam model. The empirical analysis is based on time-series data through 1991.III, prior to the switch in campaign emphasis from light to heavy beef users. It differs from Ward and Lambert's analysis covering the same period in that a systems approach is used to estimate advertising effects and simulations are performed using a structural model of the entire meat sector, not just beef.

A key finding is that beef advertising generates negative externalities for the poultry sector, which raises questions about whether the beef checkoff program is welfare increasing for meat producers as a group.

Model

The partial-equilibrium model used in this study consists of four sets of equations describing retail demand, farm supply, retail-farm price transmission, and marketing equilibrium as follows:

Retail Demand

$$Q_1 = f\,(P_1, P_2, P_3, Z, A_1) \tag{1a}$$
$$Q_2 = f\,(P_1, P_2, P_3, Z, A_1) \tag{1b}$$
$$Q_3 = f\,(P_1, P_2, P_3, Z, A_1) \tag{1c}$$

Farm Supply

$$X_1 = g\,(W_1) \tag{2a}$$
$$X_2 = g\,(W_2) \tag{2b}$$
$$X_3 = g\,(W_3) \tag{2c}$$

Retail-Farm Price Transmission

$$W_1 = h(P_1) \quad (3a)$$
$$W_2 = h(P_2) \quad (3b)$$
$$W_3 = h(P_3) \quad (3c)$$

Market Equilibrium

$$Q_1 = \lambda_1 X_1 \quad (4a)$$
$$Q_2 = \lambda_2 X_2 \quad (4b)$$
$$Q_3 = \lambda_3 X_3 \quad (4c)$$

where Q_i is the retail quantity of the *i*th meat (i = 1, 2, 3 for beef, pork, and poultry, respectively); P_i is the retail price of the *i*th meat, X_i is the farm (liveweight) quantity of the *i*th meat; W_i is the farm price of the *i*th meat; $\lambda_i = Q_i/X_i$ is the carcass-to-retail conversion factor for the *i*th meat (Duewer, Krause, and Nelson), hereafter referred to as the "dressing percentage"; Z is health information; and A_1 is beef advertising. The model consists of 12 equations in 12 endogenous variables (six price variables and six quantity variables) and 2 exogenous variables, Z and A_1.

The effect of increased beef advertising and health information on retail price can be determined by solving the structural model for the reduced form. First, express equations (1) - (4) in logarithmic differentials:

Retail Demand

$$d\ln Q_1 = N_{11}\, d\ln P_1 + N_{12}\, d\ln P_2 + N_{13}\, d\ln P_3 + G_1\, d\ln Z + B_1\, d\ln A_1 \quad (5a)$$
$$d\ln Q_2 = N_{21}\, d\ln P_1 + N_{22}\, d\ln P_2 + N_{23}\, d\ln P_3 + G_2\, d\ln Z + B_2\, d\ln A_1 \quad (5b)$$
$$d\ln Q_3 = N_{31}\, d\ln P_1 + N_{32}\, d\ln P_2 + N_{33}\, d\ln P_3 + G_3\, d\ln Z + B_3\, d\ln A_1 \quad (5c)$$

Farm Supply

$$d\ln X_1 = E_1\, d\ln W_1 \quad (6a)$$
$$d\ln X_2 = E_2\, d\ln W_2 \quad (6b)$$
$$d\ln X_3 = E_3\, d\ln W_3 \quad (6c)$$

Price Transmission

$$d\ln W_1 = T_1\, d\ln P_1 \quad (7a)$$
$$d\ln W_2 = T_2\, d\ln P_2 \quad (7b)$$
$$d\ln W_3 = T_3\, d\ln P_3 \quad (7c)$$

Market Equilibrium

$$d\ln Q_1 = d\ln X_1 \quad (8a)$$
$$d\ln Q_2 = d\ln X_2 \quad (8b)$$
$$d\ln Q_3 = d\ln X_3 \quad (8c)$$

where N_{ij} are demand elasticities with respect to price; G_i are demand elasticities with respect to health information; B_i are demand elasticities with respect to beef advertising; E_i are farm-level supply elasticities; and T_i are retail-farm elasticities of price transmission. The equilibrium condition (equations (8a) - (8c)) implicitly assumes that the dressing percentage is constant, a maintained hypothesis in this study.

Substituting (5) - (7) into (8) yields the following matrix representation of market equilibrium:

$$\begin{bmatrix} E_1T_1 & 0 & 0 \\ 0 & E_2T_2 & 0 \\ 0 & 0 & E_3T_3 \end{bmatrix} \begin{bmatrix} dlnP_1 \\ dlnP_2 \\ dlnP_3 \end{bmatrix} = \begin{bmatrix} N_{11} & N_{12} & N_{13} \\ N_{21} & N_{22} & N_{23} \\ N_{31} & N_{32} & N_{33} \end{bmatrix} \begin{bmatrix} dlnP_1 \\ dlnP_2 \\ dlnP_3 \end{bmatrix} + \begin{bmatrix} G_1 \\ G_2 \\ G_3 \end{bmatrix} dlnZ + \begin{bmatrix} B_1 \\ B_2 \\ B_3 \end{bmatrix} dlnA_1 \quad (9)$$

The left-hand side of (9) indicates the influences of supply-side and marketing forces on market equilibrium; the right-hand side reflects demand-side influences. Denoting the diagonal matrix as **S** and the square matrix as **N**, (9) can be expressed symbolically as:

$$(\mathbf{S} - \mathbf{N})\ \mathbf{dln\ P} = \mathbf{G}\ \text{dln } Z + \mathbf{B}\ \text{dln } A_1. \quad (10)$$

where **G** is a vector of health information elasticities, **B** is a vector of advertising elasticities, and **dln P** is a vector of retail price changes.

The reduced form for retail price changes can now be obtained by premultiplying (10) by $(\mathbf{S} - \mathbf{N})^{-1}$:

$$\mathbf{dln\ P} = (\mathbf{S} - \mathbf{N})^{-1}\ \mathbf{G}\ \text{dln } Z + (\mathbf{S} - \mathbf{N})^{-1}\ \mathbf{B}\ \text{dln } A_1,$$

which can be written more compactly as:

$$\mathbf{dln\ P} = \mathbf{F}\ \text{dln } Z + \mathbf{H}\ \text{dln } A_1 \quad (11)$$

where **F** and **H** are 3 x 1 vectors of reduced-form coefficients associated with dln Z and dln A_1, respectively. Equation (11) measures the net effect of an increase in health information and beef advertising on retail prices, taking into account advertising spillover, cross-commodity substitution and supply response. The corresponding net impacts on farm prices and quantities are obtained through back-substitution of (11) into (7) and (6), respectively.

Demand Estimation

Model

The demand, health information, and advertising elasticities for use in the foregoing structural model were estimated using a Rotterdam model as follows:

$$w_i\ dln\ q_i = a_i + b_i\ dln\ Q + \textstyle\sum_j^4 c_{ij}\ dln\ p_j + \sum_k^3 d_{ik}\ dln\ A_k + \sum_k^3 e_{ik}\ dln\ A_{k-1} + f_i\ dln\ Z + g_i\ dln\ Z_{-1} + \sum_m^3 h_{im}\ D_m + v_i \quad (12)$$

where i indexes the equation (i = 1, 2, 3, 4 for beef, pork, fish, and poultry, respectively) and $dln\ Q = \sum_i w_i\ dln\ q_i$ is the Divisia volume index.

In this model, w_i corresponds to the expenditure share of meat item i in time period t, q_i denotes per capita consumption of meat item i in time period t, p_j is the nominal price of meat item j in time period t, A_k is the real per capita generic advertising expenditure on meat item k in period t, Z is a health information index, and v_i is a random error term. Because the model is based on quarterly data, three binary variables D_m are specified to account for seasonal shifts in meat demands. An intercept is included in equation (12) to test whether trend-related changes in demographics or meat composition affect meat demand.

An implicit assumption underlying equation (12) is that *brand* advertising has no effect on aggregate demand. Thus, poultry advertising, which is strictly brand based, is excluded from the model.

A special feature of the Rotterdam model is that the price coefficients can be interpreted as Hicksian elasticities (N_{ij}^*) weighted by respective budget shares, i.e., $c_{ij} = w_i N_{ij}^*$. Thus, symmetry and homogeneity are easily tested by imposing, respectively, the parametric restrictions $c_{ij} = c_{ji}$ for all i and j and $\sum_j c_{ij} = 0$ for all i. Moreover, Selvanathan shows that advertising coefficients must sum to zero, i.e., $\sum_k d_{ik} = 0$ and $\sum_k e_{ik} = 0$ for all i.

Theil's theory that advertising affects the marginal utility of the advertised good but leaves the marginal utility of other goods unchanged implies that the advertising coefficients in equation (12) are proportional to the negative of the price coefficients. However, to satisfy demand theory, the price coefficients in equation (12) must be symmetric. Theil's proportionality hypothesis, therefore, is tantamount to assuming that advertising coefficients are symmetric. Advertising symmetry is tested by forming the hypothesis:

$$H_N\colon d_{ik} + e_{ik} = d_{ki} + e_{ki} \qquad (13)$$
$$H_A\colon H_N \text{ not true}$$

for all i and k with non-zero advertising. Hypothesis (13) represents a test of linear restrictions, hence it can be tested using the Wald criterion (Greene 1993, pp. 189-191).

Engel aggregation requires that $\sum_i b_i = 1$. Based on the proposition that an advertising-induced increase in the demand for one commodity must be offset by a decrease in the demand for at least one other commodity if the budget constraint is to be satisfied, Basmann (p. 53) developed an adding-up restriction for advertising responses, namely:

$$\sum_i w_i B_{ik} = 0 \qquad (14)$$

for all k. In terms of equation (12), the Basmann aggregation condition implies that $\sum_i d_{ik} = 0$ for the contemporaneous advertising responses, and $\sum_i e_{ik} = 0$ for the lagged responses. From Basmann's analysis, it follows directly that the coefficients of Z and Z_{-1} must also sum to zero across equations, i.e., $\sum_i f_i = 0$ and $\sum_i g_i = 0$. Given that equation (12) is a first-difference model, the intercepts must sum to zero, i.e., $\sum_i a_i = 0$. Likewise, the seasonality coefficients must sum to zero, i.e., $\sum_i h_{im} = 0$ for all m. Finally, the price coefficients across equations must sum to zero, i.e., $\sum_i b_{ij} = 0$.

In estimation, one equation is dropped from the system to avoid singularity in the variance/covariance matrix. Because the adding-up conditions are used to obtain coefficients for the deleted equation, adding up is treated as a maintained hypothesis in the Rotterdam model. In addition, the differentials in equation (12) are approximated by first differences and the coefficients are regarded as fixed constants even though they embed budget shares, which generally change over time.

Elasticities are calculated using the expressions:

(expenditure elasticities)	$E_i^Y = b_i / w_i$
(Hicksian price elasticities)	$N_{ij}^* = c_{ij} / w_i$
(advertising elasticities)	$B_{ik} = (d_{ik} + e_{ik}) / w_i$
(health information elasticities	$G_i = (f_i + g_i) / w_i$

The Hicksian elasticities estimated from the Rotterdam model can be converted to Marshallian demand elasticities using the Slutsky equation[2]:

$$N_{ij} = N_{ij}^* - w_j E_i^Y.$$

Expenditure elasticities are expected to be positive, own-price elasticities negative, and the Hicksian cross-price elasticities are expected to be positive, since meat products are generally considered to be normal goods and to substitute for each other. The own-advertising elasticities should be positive and the cross-advertising elasticities negative. The health information elasticities are expected to be positive for poultry and fish and negative for beef and pork because red meat consumption is implicated in heart disease and health authorities encourage the consumption of fish and poultry as a healthy alternative.

Data

Data for the period 1976.II through 1991.III are used to estimate the model. (The first observation is lost due to lagged variables in the model.) Price and quantity data for beef, pork, and poultry were obtained from Putman and Allhouse and USDA's *Livestock and Poultry Situation and Outlook Report*. Price data for fish were obtained by dividing per capita expenditure data from a 1982-84 USDA survey by per capita fish consumption to get a base price. This base price was then multiplied by the quarterly CPI for fish to get a time series. Fish consumption data were obtained following the procedure outlined in Schmitz and Capps (p. 10). The consumer price index (CPI) compiled by Bureau of Labor Statistics was used as a deflator for advertising.

The advertising data were obtained from quarterly issues of *AD $ SUMMARY* published by the Leading National Advertisers, Inc. The beef, pork, and fish advertising data are those reported by LNA for the Beef Industry Council, the National Pork Producers Council, and the National Fish and Seafood Council, respectively. To accommodate the logarithmic specification of the Rotterdam model, the problem of zero advertising expenditures in some periods was addressed by adding a small positive number (0.0001) to *each* observation (zero and positive values alike) *after* deflation by population and the CPI.

A health information index was constructed using Brown and Schrader's cholesterol information index as basic data, updated through 1991.III. Brown and Schrader developed two data series, one that indicated the cumulative sum of articles appearing in medical journals that support the link between blood serum cholesterol and heart disease ("negative information"), and another that indicated the cumulative number of articles that attacked or questioned the link ("positive information"). Following Chang and Kinnucan (1991a), we combined the two basic data series into a single index using the formula:

$$Z_t = \omega_t \, NEG_t \tag{15}$$

where Z_t is the "net-publicity" about the link between cholesterol and heart disease. In equation (15), NEG_t is Brown and Schrader's "negative information" index, and ω_t is a weighting factor that indicates the relative proportion of all articles in period t that are negative, i.e., $\omega_t = NEG_t/(NEG_t + POS_t)$ where POS_t is the cumulative total of "positive" articles.

Estimation Procedures

The model was estimated using seemingly unrelated regressions (SUR) to accommodate the imposition of parametric restrictions. The SUR procedure was selected because preliminary analysis provided only weak evidence that prices and expenditures are endogenous. In particular, a Hausman test (Greene 1993, p. 479) rejected the exogeneity hypothesis at the 5% level but not the 1% level.

Maximum likelihood estimation of a SUR constrained system produces parameter estimates that are invariant to the deleted equation (Greene 1992, pp. 390-92). To facilitate tests of the advertising restrictions, we deleted the poultry equation.

Results

Preliminary tests based on the *D.W.* statistic showed no evidence of serial correlation in the unrestricted equations. Wald tests for various combinations of the theoretical restrictions indicated that all restrictions are compatible with the data (Table 1). The compatibility of the advertising and health information restrictions with the data is noteworthy, as these restrictions have not been tested before in the literature. Theil's hypothesis that advertising elasticities are proportional to demand elasticities is consistent with these data.

Table 1. Wald Tests of Theoretical Restrictions

Restriction	Computed χ^2	Critical χ^2	Test Result
PH, PS	4.8494	12.59	Fail to Reject
PH, PS, AH	10.3745	16.92	Fail to Reject
PH, PS, AS	7.1752	16.92	Fail to Reject
PH, PS, AH, AS	10.6933	21.03	Fail to Reject

Note: PH = price homogeneity, PS = price symmetry, AH = advertising homogeneity, and AS = advertising symmetry

Regression results for the model with price homogeneity and price and advertising symmetry imposed are reported in Table 2. The relatively high R^2s, which range from 0.80 for fish to 0.92 for pork, coupled with a preponderance of significant coefficients, suggest the restricted model provides a good fit to the data. The results overall suggest that meat demands are subject to seasonal variation and trend effects. Estimated price effects and expenditure effects in general are consistent with *a priori* expectations.

The price elasticities, evaluated at 1990 data points and reported in Table 3, indicate that the three meat items of interest in this study have inelastic demands. The positive Hicksian cross elasticities of beef, with respect to poultry and pork, indicate that these two goods are net substitutes for beef. The estimated own-price Hicksian elasticities of -0.48 and -0.63 for beef and pork, respectively, compare favorably with Dahlgren's (p. 199) estimates (evaluated at 1985 data points) of -0.66 and -0.58. Poultry's own-price elasticity of -0.14 is smaller than that usually found in the literature (e.g., Dahlgren's estimate is -0.60), but is not too different from Capps and Schmitz's (p.30) *compensated* elasticity estimate of -0.22.

The estimated health-information effects are significant (one-tail *t*-test) at the 10% level or lower in all equations but fish. The health-information effects are negative for beef and pork and positive for poultry, as expected. The elasticity estimates corresponding to the significant coefficients in Table 2, evaluated at 1990 data points, are -0.648, -0.605, and 1.34 for beef, pork, and poultry, respectively. Corresponding estimates by Schmitz and Capps (p. 21) are -1.17, -0.448, 1.92.

The estimated effects of beef advertising, the key policy variable in this study, are significant in the beef and poultry equations, but not the pork equation. The contemporaneous coefficients for beef advertising in the beef and pork equations are not significant, which suggests that it takes one calendar quarter for advertising to "take hold" in these markets. Based on the one-period lag coefficients, the estimated own-advertising elasticity for beef is 0.00287 and the estimated cross-advertising elasticity with respect to poultry is -0.00360. Thus, it appears that beef advertising increases the demand for beef, has no *direct* effect on pork demand, and decreases the demand for poultry.

The own-advertising elasticity for beef of 0.0029 may be compared to the advertising elasticity of 0.0075 for catfish estimated by Zidack, Kinnucan and Hatch. That the health information elasticity for beef (-0.648) is much larger in absolute value than the own-advertising elasticity is consistent with Chang and Kinnucan's (1991a) findings for butter, and may reflect the greater credence value of information provided by health authorities vis-a-vis industry.

Parameterization

The elasticities from the foregoing estimation and other parameters needed to simulate the structural market model are listed in Table 3. For the price elasticities, we list both the Hicksian and the Marshallian elasticities for sensitivity analysis purposes. The cross-advertising elasticity for pork (B_2 in equation (5b)) is set to zero because the estimated Rotterdam coefficients for this variable were not significant. All elasticities are evaluated at 1990 data points, so that they are consistent with the 1990 baseline values for prices and quantities.

The supply elasticities listed in Table 3 were obtained from published sources (see table footnotes for references). These elasticities are the ones used in the "upward-sloping supply" scenario discussed later. For the "fixed-supply" scenario, the supply elasticities for beef, pork, and poultry are set to zero.

Table 2. SUR Estimates of Rotterdam Model of Meat Demand with Homogeneity, Symmetry, and Advertising Symmetry Restrictions Imposed, U.S. Data, 1976.II - 1991.III Sample Period

	Dependent	Variables		
Independent Variables	QBEEF	QPORK	QPOULT	QFISH
PBEEF	-.21883 (-5.385)			
PPORK	.15023 (7.502)	-.16027 (-9.272)		
PPOULT	.05145 (3.688)	-.01573 (-1.811)	-.02607 (-2.539)	
PFISH	.01714 (0.521)	.02576 (1.403)	-.00965 (-0.804)	-.03326 (-0.902)
EXPENDITURE	.51763 (8.449)	.24739 (6.139)	.00765 (0.339)	.22733 (3.532)
CHO_t	-.29505 (-1.883)	.10510 (1.017)	.17139 (3.018)	.01856 (0.144)
CHO_{t-1}	-.05744 (-0.366)	-.15319 (-1.478)	.08460 (1.464)	.12603 (0.771)
$BFAD_t$	-.00077 (-1.191)	.00042 (1.133)	-.00045 (-1.193)	.00079 (1.389)
$BFAD_{t-1}$	.00135 (1.974)	-.00038 (-.934)	-.00068 (-1.821)	-.00030 (-0.503)
$PKAD_t$	-.00021 (-0.938)	-.00003 (-0.166)	.00003 (0.268)	.00022 (1.161)
$PKAD_{t-1}$	.00026 (1.141)	.00003 (0.182)	-.00011 (-1.106)	-.00018 (-0.949)
$FSAD_t$	.00022 (0.917)	-.00006 (-0.415)	.00008 (0.879)	-.00023 (-0.927)
$FSAD_{t-1}$	.00028 (1.175)	.00001 (0.656)	-.00015 (-1.725)	-.00022 (-0.886)
D1	.03230 (7.917)	-.03490 (-12.816)	-.03367 (-21.489)	.03626 (8.377)
D2	.00919 (2.280)	-.04026 (-15.327)	-.00237 (-1.620)	.03344 (8.009)
D3	.00247 (0.603)	-.02898 (-10.344)	-.00540 (-3.522)	.03191 (7.499)
INTERCEPT	-.00557 (-1.157)	.02673 (8.376)	.00639 (3.608)	-.02755 (-5.503)
R^2	0.8281	0.9185		0.8008
D-W Stat[a]	2.9524	2.3338		2.9136

Note: Numbers in parenthesis are the *t*-values for the parameter estimates.
[a] Durbin-Watson *d* Statistic: n=61, k'=16, α=0.01, d_L=0.857, d_U=2.120, the zone of indecision is 1.88 -3.143.

Table 3. Parameter and Baseline (1990) Values for U.S. Beef, Pork, and Poultry Industries

Parameter/ Variable	Definition	Value		
		Beef	Pork	Poultry
N_{1j}	Demand elasticity w.r.t. beef price	-0.998 (-0.481)[a]	0.149 (0.594)	0.251 (0.269)
N_{2j}	Demand elasticity w.r.t. pork price	0.042 (0.330)	-0.881 (-0.633)	-0.092 (-0.082)
N_{3j}	Demand elasticity w.r.t. poultry price	-0.104 (0.113)	-0.249 (-0.062)	-0.144 (-0.136)
B_i	Advertising elasticity w.r.t. beef advertising	0.00287	0.0	-0.00360
E_i	Farm-level supply elasticity	0.15[b]	0.40[c]	0.31[d]
S_i^f	Farmer's share of consumer dollar[e]	0.60	0.41	0.51
e_b	Elasticity of supply of marketing services[f]	10.00	10.00	10.00
T_i	Elasticity of retail-farm price transmission[g]	1.65	2.31	1.90
A_1	Beef advertising expenditures (mil $)	30.0	--	--
P_i	Retail price ($/lb)[h]	2.81	2.13	0.90
Q_i	Retail quantity (lbs/capita)[i]	67.0	51.1	83.4
$P_i\, Q_i$	Total consumer expenditures (bil. dol.)[j]	46.5	26.9	18.5

[a] Number in parenthesis is the Hicksian elasticity estimated from the Rotterdam model and evaluated at 1990 data points; number above the parenthesis is the corresponding Marshallian elasticity.

Sources: [b]Ospina and Shumway; [c]Lemieux and Wohlgenant; [d]Aradhyula and Hollywood; [e]Dunham, p. 5; [f]Assumed value; [g] Based on the foregoing parameters and text equation (16); [h]Duewer *et al.*, Table 3, 1990 figure; [i]Duewer *et al.*, Table 2, 1990-92 average; [j]Based on a US 1990 population of 246.9 million.

The price-transmission elasticities in Table 3 were computed from the theoretical price transmission equation (Gardner, p.403):

$$T_i = (\sigma_i + e_b) / [\sigma_i + S_i^f e_b + (1 - S_i^f) E_i]. \tag{16}$$

where σ_i is the elasticity of substitution between the farm-based input (e.g., beef carcass) and the bundle of marketing services (e.g., processing-plant labor and energy); e_b is the elasticity of supply of marketing services; S_i^f is the cost share of the farm-based input; and E_i is the previously defined supply elasticity. Equation (16) specifies the price transmission elasticity when the farm supply curve is stable and observed changes in the marketing margin are due to isolated shifts in retail demand (e.g., see Kinnucan and Forker). The equation assumes competitive market clearing and constant returns to scale, conditions that appear to apply to the U.S. meat sector (Wohlgenant, 1989).

The cost-share parameter values in equation (16) are listed in Table 3. Owing to our earlier assumption that the dressing percentage is constant, which implies fixed-proportions, σ_i in equation (16) is set to zero. Because no empirical estimates of e_b exist and preliminary experimentation indicated results were not sensitive to alternative values, we set e_b equal to 10.

Simulation

Because a purpose of this study is to illustrate cross-commodity substitution and supply-response effects, two sets of simulations are performed. In the first set, we use the Marshallian demand elasticities listed in Table 3. In the second set, we replace the Marshallian elasticities with Hicksian elasticities. Each set presents the estimated price and quantity effects of a 10% increase in beef advertising for fixed and upward-sloping supply holding constant the effect of health information, i.e., dlnZ in equation (11) is set to zero.

Results confirm the importance of cross-commodity substitution and supply response in the measurement of advertising effects (Table 4). Although poultry prices are always negatively affected by an increase in beef advertising, the effect of an increase in beef advertising on beef prices depends critically on supply response. If supply is upward-sloping, an increase in beef advertising increases beef price, as might be expected given the positive own-advertising elasticity. However, if meat supplies are fixed, an increase in beef advertising *reduces* beef price.

The intuition behind this perhaps surprising result inheres in the "feedback effects" of the beef advertising onto the poultry and pork markets. Specifically, holding prices constant, an increase in beef advertising causes a reduction in poultry demand, which places downward pressure on poultry price. As the markets equilibrate to eliminate the excess supply in the poultry market caused by the advertising increase, poultry prices decline, which causes the demand curves in the pork and beef markets to shift down. If the downward shift in beef demand associated with these "feedback effects" is larger than the upward shift in beef demand caused by the advertising (direct effect), beef price declines. The explanation for the negative own-price effects observed in Table 4 is that the feedback effects dominate the direct effect when meat supplies are fixed.

The simulations highlight a second point: even though an advertising cross-elasticity is zero (e.g., beef advertising with respect to pork demand), this does not mean that the market in question (e.g., pork) is unaffected by advertising. Rather, spillover effects still occur if the markets are related through consumer preferences and advertising causes changes in relative prices. In the case of pork, an increase in beef advertising generates a positive externality in the sense that pork price increases (except when supply is fixed and substitution is Hicksian, see Table 4). The positive spillover of beef advertising into the pork market arises strictly due to advertising's *price effects*, as the cross-advertising elasticity between beef and pork is zero.

The quantity effects of an increase in beef advertising are modest and sensitive to the assumptions about cross-commodity substitution (Table 4). In general, Hicksian substitution

Table 4. Price and Quantity Impacts of a 10% Increase in Beef Advertising Under Alternative Assumptions About Supply Response and Cross-Commodity Substitution

Variable	Marshallian Substitution		Hicksian Substitution	
	Fixed Supply	Upward-Sloping Supply	Fixed Supply	Upward-Sloping Supply
Retail Prices:	(% change)			
Beef	-0.0353	0.0129	-0.4449	0.0297
Pork	0.0266	0.0029	-0.1608	0.0087
Poultry	-0.270	-0.0519	-0.5472	-0.0455
Farm Prices:				
Beef	-0.0588	0.0214	-0.7415	0.0490
Pork	0.0648	0.0068	-0.3922	0.0201
Poultry	-0.5303	-0.0987	-1.0728	-0.0866
Quantity:				
Beef	0.00	0.0032	0.00	0.0074
Pork	0.00	0.0027	0.00	0.0080
Poultry	0.00	-0.0594	0.00	-0.0268

magnifies quantity effects in the beef and pork markets and attenuates the quantity effect in the poultry market. So long as supply is upward sloping, an increase in beef advertising increases beef and pork quantities and decreases poultry quantity.

Welfare Effects

Given the modest price and quantity impacts of beef advertising indicated in Table 4, an interesting question to ask is whether the beef advertising program generates sufficient profit to compensate for costs. To answer this question, and to consider the distributional impacts of beef advertising, the price and quantity impacts reported in Table 4 were converted to welfare measures using the following equation:

$$\Delta PS_i = S_i^f \, P_i \, Q_i \, \text{dln}\, W_i \ \ (1 + 0.5 \, \text{dln}\, X_i) \tag{17}$$

where ΔPS_i is the change in "producer surplus" for the ith meat product and the other variables are as previously defined. Producer surplus measures producer returns to increased advertising after all economic costs associated with producing the additional output have been subtracted.

The validity of equation (17) rests on the assumption that advertising generates *parallel* shifts in *linear* demand schedules (Just, Hueth, and Schmitz). Although this assumption may not be strictly true in any given application, the approximation error is probably negligible if the equilibrium displacements being considered are small, as is the case here.

An additional caveat is that the surplus measure given in (17) is a *gross* measure in that the effects of the advertising "tax" on the supply schedules for the respective meat items are not taken into account. The beef checkoff in general is expected to shift up the supply schedule for beef and may have spillover effects onto pork and poultry supplies. Moreover, a portion of the checkoff is shifted to consumers unless supply is fixed (Chang and Kinnucan 1991b). The *net* changes in surplus can be approximated by subtracting from equation (17) advertising's incremental cost. However, because of tax shifting, the net surplus measures so computed will *understate* the true impacts when supply is upward sloping.

With the above caveats in mind, changes in producer surplus associated with a 10% increase in beef advertising were computed using 1990 baseline values for prices, quantities, and cost-shares listed in Table 3 and the price and quantity changes listed in Table 4 for upward-sloping supply. To determine the sensitivity of results to assumptions about price transmission, and to shed light on the implications of ignoring the marketing channel a la Alston, Chalfant, and Piggott, we ran simulations with the price transmission elasticities for each commodity set to one. Setting $T_i = 1$ is tantamount to assuming that derived-demand elasticities are identical to their primary demand counterparts, an assumption that in general is not expected to hold.[3]

Results suggests that the surplus changes internal to the beef industry are sufficient to compensate for the incremental cost of the program so long as derived demand is less elastic than primary demand, i.e., $T_i > 1$, or substitution is Hicksian (Table 5). That is, given the $3 million outlay represented by a 10% advertising increment, the simulated increases in producer surplus in the beef market under these conditions ($6.0 - $13.6 million) are sufficient to cover incremental costs. (The implied marginal *net* benefit-cost ratios are 1.0:1 and 3.6:1, respectively, which may be compared to Ward and Lambert's point estimate of 5.7:1.)

Table 5. Producer Surplus Impacts of a 10% ($3 Million) Increase in Beef Advertising Under Alternative Assumptions About Retail-Farm Price Transmission and Cross-Commodity Substitution

Commodity	Marshallian Substitution		Hicksian Substitution	
	$T_i > 1$[a]	$T_i = 1$	$T_i > 1$	$T_i = 1$
	------------ million dollars ------------			
Beef	6.0	2.1	13.6	7.5
Pork	0.8	0.7	2.2	1.6
Poultry	- 9.3	- 8.0	- 8.2	- 7.8
All	- 2.6	- 5.2	7.6	1.9

[a] T_i refers to the elasticity of retail-farm price transmission (see Table 3 for the actual numerical values). Setting $T_i = 1$ is analytically equivalent to assuming that primary- and derived-demand elasticities are equal. These simulations assume upward-sloping supply.

When spillover effects are taken into account, the producer welfare effects of increased beef advertising are less clear. In particular, increased beef advertising generates negative externalities for the poultry industry, and these externalities loom large (in a relative sense) when substitution is Marshallian (Table 5). If substitution is Hicksian, an increase in beef advertising generates a welfare improvement for meat producers as a group. If substitution is Marshallian, an increase in beef advertising still generates positive externalities for pork producers, but the combined benefits to beef and pork producers are not sufficient to offset the losses sustained by poultry producers.

Ignoring the marketing channel has important consequences for welfare measurement. In particular, both the direct and spillover effects are understated (in absolute value) when no distinction is made between markets at farm and retail. The bias is especially severe in the measurement of direct effects: incremental returns to increased beef promotion are understated by a factor of 1.8 to 2.9 (Table 5). Biases of this magnitude, which are consistent with predictions based on the Dorfman-Steiner theorem, could result in inference reversals with respect to whether programs are cost effective. Thus, from a research perspective, taking into account the multi-stage food production process appears to be an important element in accurate benefit-cost analyses of commodity promotion programs.

Concluding Comments

A major theme of this paper is that the economic impacts of cooperative advertising ventures are sensitive to supply response and cross-commodity substitution. The issue of cross-commodity substitution is particularly germane in the analysis of meat promotion, as meats are expensive and consumers will react to changes in relative prices induced by advertising by substituting less expensive meat products for the relatively more costly items.

Consistent with Ward and Lambert's analysis, we find that an increase in beef advertising generates a positive marginal return to beef producers. Moreover, our analysis suggests that the beef advertising program has generated positive externalities for the pork sector, not because beef advertising increased pork demand *per se*, but because cross-commodity substitution engendered by the beef campaign's price impacts was favorable for pork.

The clear loser in the beef industry's demand-enhancement endeavors is the poultry sector. Estimates from a Rotterdam model of U.S. meat demand indicate an inverse relationship between beef advertising expenditures and poultry consumption. Simulations of the structural model based on these demand estimates suggest that increases in beef advertising cause relatively large reductions in producer surplus in the poultry sector. The negative externalities for poultry are large enough to suggest that meat producers as a group may be worse off. Although this point is debatable and merits further research, the beef campaign clearly has distributional consequences, with pork and beef producers benefitting at the expense of poultry producers.

A caveat in interpreting our findings is that the empirical analysis is based on data that terminates in 1991.III, prior to the shift in campaign emphasis from light to heavy beef users. If the new campaign strategy results in different advertising effects, or sample updating affects elasticities, different conclusions might be warranted.

Footnotes

1. Intuitively, ignoring the marketing channel will result in understated returns (or exaggerated losses) when derived demand is less elastic than primary demand (e.g., see the Dorfman-Steiner theorem). We return to this issue later.

2. Technically, the Slutsky condition, as specified, overstates income effects in that the two-stage budgeting process implicit in the Rotterdam specification discussed earlier is ignored. The correct equation is: $N_{ij} = N_{ij}^{*} - s_j\, M\, E_i^{Y}$ where s_j is the budget-share of the jth meat item with respect to *total income* (not meat expenditure) and M is the income elasticity of meat demand with respect to total consumer income. Because meat items account for less than 3% of consumer expenditures in the United States, $s_j\, M$ is expected to be smaller than w_j, and will be close to zero if the income elasticity for meats is small. Thus, in the simulations reported later, the "Hicksian-substitution" scenarios are probably closer to the "truth" than the "Marshallian-substitution" scenarios.

3. To see why, consider the following Hicksian expression for the elasticity of derived demand:

$$\lambda = k\,\eta + (1 - k)\,\sigma$$

where λ is the elasticity of demand for the raw factor (e.g., live pig); η is the elasticity of demand for the final product (e.g., pork chops), defined to be positive for normal goods; k is the share of the raw factor in total cost, and σ is the elasticity of substitution between the raw factor and a co-operant factor (e.g., plant labor) used in the production of the final product. This expression assumes that the supply schedule for the co-operant factor is horizontal (Bronfenbrenner, p. 259), a common assumption in the applied literature (e.g., Wohlgenant, 1993). If $\lambda = \eta$, then it follows immediately that $\eta = \sigma$. Although research suggests substitution elasticities for U.S. meats are non-zero in the "long run" (Wohlgenant, 1989), they are not likely to be identically equal to demand elasticities. For "short-run" analysis of the type considered here (three years or less), fixed proportions may be more plausible than variable proportions, in which case $\sigma = 0$ and unitary transmission elasticities violate theory (unless primary demands are perfectly inelastic).

References

Alston, J. M, J. A. Chalfant, and N. E. Piggott. "Demand Response and Returns to Incremental Advertising in the Australian Meat Industry." This volume.

Aradhyula, S. V., and M. T. Hollywood. "Risk Behavior and Rational Expectations in the U.S. Broiler Market." *American Journal of Agricultural Economics* 71(1989):892-902.

Basmann, R. L. "A Theory of Demand with Variable Consumer Preferences." *Econometrica* 24(1956):47-58.

Bronfenbrenner, M. "Notes on the Elasticity of Derived Demand." *Oxford Economic Papers* 13 (1961): 254-61.

Brown, D., and L. Schrader. "Information on Cholesterol and Falling Shell Egg Consumption." *American Journal of Agricultural Economics* 72(1990):548-55.

Capps, O., Jr., and J. D. Schmitz. "A Recognition of Health and Nutrition Factors in Food Demand Analysis." *Western Journal of Agricultural Economics* 16(1991):21-35.

Chang, H.-S., and H. W. Kinnucan. "Advertising, Information, and Product Quality: The Case of Butter." *American Journal of Agricultural Economics* 73(1991a):1195-1203.

Chang, H.-S., and H. W. Kinnucan. "Economic Effects of an Advertising Excise Tax." *Agribusiness* 7(1991b):165-73.

Dahlgran, R. A. Is U.S. Meat Demand in Equilibrium? in *The Economics of Meat Demand*, Rueben C. Buse (editor). Proceedings of South Carolina Conference, 1989.

Dorfman, R., and P. O. Steiner. "Optimal Advertising and Optimal Quality." *American Economic Review* 44 (1954):826-36.

Duewer, L. A., K. R. Krause, and K. E. Nelson. *U.S. Poultry and Red Meat Consumption, Prices, Spreads, and Margins.* USDA. ERS. Agr. Info. Bull. No. 684. October 1993.

Dunham, D. *Food Costs...From Farm to Retail in 1990.* USDA, ERS, Agr. Info. Bull. No. 619. March 1991.

Gardner, B. L. "The Farm-Retail Price Spread in a Competitive Food Industry." *American Journal of Agricultural Economics* 66(1975):339-409.

Greene, W. H. *Econometric Analysis.* Second Edition. New York: Prentice Hall, 1993.

Greene, W. H. *LIMDEP Version 6.0 User's Manual and Reference Guide.* New York: Econometric Software, Inc., 1992.

Just, R. E., D. Hueth, and A. Schmitz. *Applied Welfare Analysis and Public Policy.* New Jersey: Prentice-Hall, Inc.

Kinnucan, H. W., and O. D. Forker. "Asymmetry in Farm-Retail Price Transmission for Major Dairy Products." *American Journal of Agricultural Economics* 69(1987):285-92.

Leading National Advertisers, Inc. *AD $ SUMMARY.* New York. Various issues, 1975-91.

Lemieux, C. M., and M. K. Wohlgenant. "*Ex Ante* Evaluation of the Economic Impact of Agricultural Biotechnology: The Case of Porcine Somatotropin." *American Journal of Agricultural Economics* 71(1989):903-14.

Muth, R. E. "Derived Demand Curve for a Productive Factor and the Industry Supply Curve." *Oxford Economic Papers* 16(1965):221-34.

Ospina, E., and C. R. Shumway. *Disaggregated Econometric Analysis of U.S. Slaughter Beef Supply.* Texas A&M University, Texas Agricultural Experiment Station Technical Monograph No. 9, 1979.

Putman, J. J., and J. E. Allshouse. *Food Consumption, Prices, and Expenditure, 1970-90.* USDA, ERS, Statistical Bulletin No. 840, 1990.

Selvanathan, E. A. "Advertising and Consumer Demand: A Differential Approach." *Economic Letters* 31(1989):215-19.

Schmitz, J. D., and O. Capps, Jr. *A Complete Systems Analysis of Nutritional Awareness and Food Demand.* College Station: Texas A&M University Agr. Exp. Sta. Bull. b-1712, March 1993.

Theil, H. *System-Wide Explorations in International Economics, Input-Output Analysis, and Marketing Research.* Amsterdam: North-Holland, 1980.

USDA, Economic Research Service. *Livestock and Poultry Situation and Outlook.* LPS-47,1990.

Ward, R. W., and C. Lambert. "Generic Promotion of Beef: Measuring the Impact of the US Beef Checkoff." *Journal of Agricultural Economics* 44(1993):456-65.

Wohlgenant, M. K. "Demand for Farm Output in a Complete System of Demand Functions." *American Journal of Agricultural Economics* 71(1989):241-52.

Wohlgenant, M. K. "Distribution of Gains from Research and Promotion in Multi-Stage Production Systems: The Case of the U.S. Beef and Pork Industries." *American Journal of Agricultural Economics* 75(1993):642-51.

Zidack, W., H. Kinnucan, and U. Hatch. "Wholesale- and Farm-Level Impacts of Generic Advertising: The Case of Catfish." *Applied Economics* 24(1992):959-68.