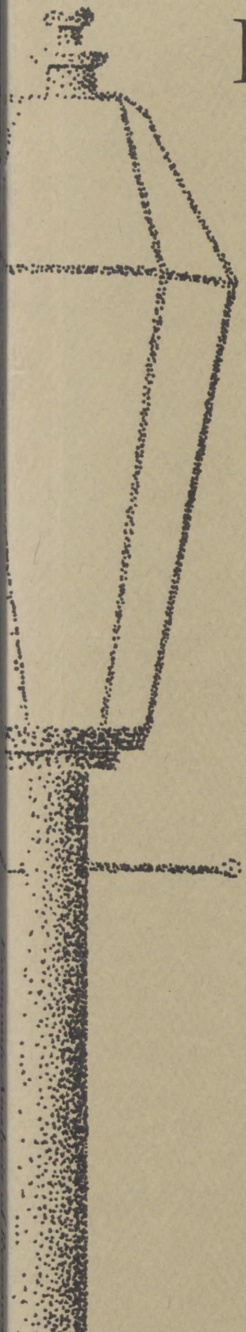

Economic Analysis of Research and Promotion

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Returns from Research and Advertising in the North American Hog and Pork Industry

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Introduction

Alternative strategies with the potential to increase producer surplus are investments that shift supply and demand curves. Cost-reducing or yield-increasing applied research lowers per unit costs of farm production, thereby shifting out the supply curve. Advertising of a retail product, if effective, will increase the consumer's willingness to pay.

Both strategies have been pursued by the Canadian and U.S. hog industries, who finance such investments with checkoff schemes--levies by marketing boards on primary producers. Total public and producer hog research expenditure in Canada in 1993, for example, was C $8.24 million (US $6.34 million) and US $82.6 million in the United States. Generic (producer-sponsored) advertising expenditures were smaller in that year--C $5.57 million (US $4.28 million) in Canada and US $12.38 million in the United States. Research has focused on improvements in a variety of dimensions, including animal weight gain, backfat thickness, feed conversion, litter size, and mortality (Huot, Fox, and Brinkman, 1988). Advertising, among other strategies, has attempted to distance pork from beef, promoting a reputation as "the other white meat." For Canada in general, producer contributions to research have been smaller than similar contributions to advertising.

The paramount concern in any study of producer-funded investment is the effectiveness of such a campaign. Other considerations are whether the mix of advertising and research investment is appropriate given a budget constraint, or whether optimal levels of each investment have been attained or exceeded. An additional set of questions is concerned with the spillover effects of such investments over time, into other countries or industries.

The objective of this paper is to specify an econometric model of North American hog and pork markets capable of measuring empirically the net producer returns from research and advertising investments. This study differs from previous studies that focused on social returns from public investment in research. The paper begins with a brief introduction to measuring returns to supply- and demand-shifting policies with the economic surplus approach. Previous studies are reviewed with respect to livestock research and meat promotion. An econometric model is then specified and applied to quarterly data from the North American hog and pork market. Next, parameter estimates are incorporated into a simulation model and used to evaluate returns to research and advertising from the Canadian perspective. The paper concludes with implications for Canadian producer investment strategies.

Returns to Research and Advertising

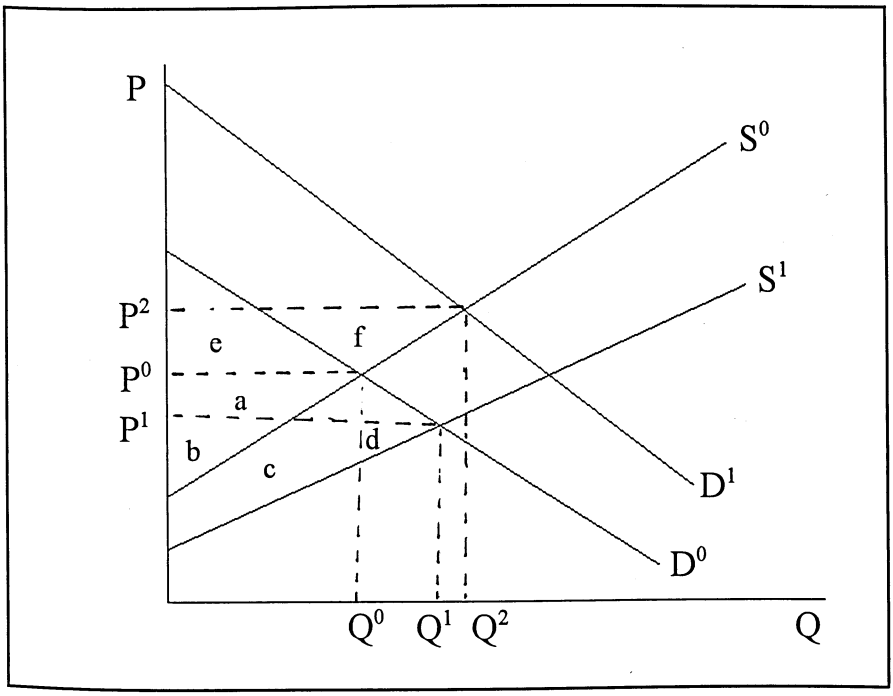
Two similar, but largely separate, streams in the economic literature have examined returns to investment in research and advertising (exceptions that examine both are Wohlgenant, 1993; Chyc and Goddard, 1994; Sellen, 1996; Weerahewa, 1997). On conceptual grounds or for practical purposes, most studies assume that research and advertising appear as separate arguments in their respective production and utility functions. Such investments thereby serve to shift supply and demand curves.

Returns to advertising are generally measured with the change in economic surplus that results from the outward shift in the demand curve (Forker and Ward, 1993). The change in consumer surplus from advertising that alters consumer's tastes and preferences has been the subject of much debate (Dixit and Norman, 1978) since traditional welfare analysis assumes constant tastes. On the producer surplus side -- the focus of this paper -- the picture is relatively clear; producers gain from advertising-induced increases in either price or quantity provided that the increase in surplus exceeds the cost of advertising. Similarly, a common approach to measuring returns to research is the "index number" approach, which considers the outward shift in supply caused by per unit cost-reducing research (Alston, Norton, and Pardey, 1995).[1] Such shifts, in the presence of inelastic demand, could potentially harm producers if the price is sufficiently depressed. By loose analogy with the advertising debate, there exists controversy about measuring returns to research if there are quality improvements, since comparable supply curves must represent a single good of uniform quality (Edwards and Freebairn, 1981, p. 22).

Changes in producer surplus resulting from policies that shift demand and supply are shown in Figure 1. From the initial equilibrium at P_0 and Q_0, a shift in demand to D_1 increases producer surplus from area $a+b$ to $a+b+e+f$. A shift in supply to S_1 results in a gain of area $c+d$ but a loss of area a because of the lower price. It should be apparent from this figure that the slopes of the supply and demand curves, and the type of shift, determine the gains (or losses) from research and advertising investment. The more inelastic the demand, for example, the more producers gain from outward shifts in demand, and the less they gain from outward shifts in supply. The type of shift has also been shown to be important; the more divergent the supply shift with respect to the Y axis, for example, the less producers gain (Lindner and Jarrett, 1988).

[1] The second most common approach is the "econometric" method, which considers the shift in the production function.

Figure 1. Returns to research and advertising



A time dimension will normally be required to compare effects of research and advertising. Advertising expenditure is more likely to have an impact on demand in the short run, after which effects will taper off unless promotion is sustained. In contrast, research expenditure is not likely to have short-run effects, particularly in livestock and tree crops, but could require several years for the process of research, extension, adoption, and supply response to take place. Specification of appropriate lags and discount rates, therefore, is particularly important in such studies.

Table 1. Studies of Returns to Research in Livestock

Study	Commodity	Country	Functional Form, Method	Research Specification	Results
Peterson (1967)	Poultry	U.S.	Linear, Econometric	No estimation; research included as supply shifter	RoR 21-25%
Bredahl & Peterson (1976)	Dairy, Poultry, Livestock	U.S.	Cobb-Douglas, Econometric	Single period model using cross-sectional RoR data	RoR 43% 37% RoR 47%
Fox (1986)	Livestock	U.S.	Cobb-Douglas, Econometric	Geometric distribution lag with 3-7 year lag for applied and basic research	RoR 150%
Huot, Fox, & Brinkman (1988)	Hogs	Canada	Linear, Semi-log, Economic Surplus	Quadratic distribution lag with 3-7 year lag	RoR 43-59%
Horbasz, Fox, & Brinkman (1988)	Sheep	Canada	Linear, Economic Surplus	PDL with 3-6 year lag	RoR 25% Elas 0.237
Widmer, Fox, & Brinkman (1988)	Beef	Canada	Semi-log, Economic Surplus	PDL with 4-16 year lag	RoR 66% Elas 0.36
Lemieux & Wohlgenant (1989)	Hogs	U.S.	Cobb-Douglas, Economic Surplus	No estimation; research included as supply shifter	10.8-16.9% short-run increase in producer surplus
Zachariah, Fox, & Brinkman (1989)	Dairy	Canada	Linear, Economic Surplus	PDL with 4-11 year lag	RoR 48% Elas 0.265
Voon & Edwards (1991)	Hogs	Australia	Linear, Economic Surplus	No estimation; research included as supply shifter	Social welfare gain of $7 million from quality improvements
Fox, Roberts, & Brinkman (1992)	Dairy	Canada	Log-log, Economic Surplus	PDL with 3-14 year lag	RoR 97% Elas 0.570
Freebairn (1992)	Dairy	Australia	Linear, Economic Surplus	Static synthetic model	Social welfare gain $9.6-53.9 million under current policy
Chyc & Goddard (1994)	Eggs	Canada	Log-log/Linear, Economic Surplus	Six period lag	Elas (log) 0.14 Elas (linear) 0.15

Note: RoR is rate-of-return; Elas is percentage change in supply given a 1 percent increase in research expenditure.

Empirical Studies

Empirical studies of advertising and research are typically expressed in rates of return, benefit-cost ratios, or elasticities -- the percentage change in consumption (supply) given a 1 percent increase in advertising (research). Some studies have examined optimal levels of research (Shumway, 1973; Knutson and Tweeten, 1979) and advertising (Nerlove and Waugh, 1961; Dorfman and Steiner, 1954; Goddard, Griffith, and Quilkey, 1992; Goddard and Conboy, 1992). Empirical studies have indicated widespread underinvestment in research (surveys appear in Norton and Davis, 1981; Echeverría, 1990). Table 1 presents selected research studies. Table 2 presents selected studies on livestock product advertising.

Table 2. Studies on Returns to Meat Advertising

Study	Commodity	Country	Functional Form	Advertising Specification	Results
Funk, Meilke, & Huff (1977)	Beef	Canada	Linear	Own & cross-advertising effects	Beef 0.12 to 0.50 Pork -0.04 to 0.13
Ball & Dewbre (1989)	Beef, Lamb, & Pork	Australia	Linear	Current period, own, and cross-advertising	7:1 benefit-cost-ratio
Goddard & Griffith (1991)	Beef, Lamb, & Chicken; Beef, Lamb, & Pork	Canada Australia	Translog, AIDS, & Log-log	Current period advertising for each meat type	Canada pork -0.27 to 0.053 Australian pork -0.006 to 0.003
Hoover, Hayenga, & Johnson (1992)	Beef	U.S.	Linear & Multi-stage	Current period with 8 quarter carryover	Consumption rose 3% in response to TV advertising campaign
Jensen & Schroeter (1992)	Beef	U.S.	Tobit model	Single period generic advertising	Persuasive advertising reduces demand
Ward & Lambert (1993)	Beef	U.S.	Log-log	Current & 1-year lag generic advertising	Retail beef 0.054 Boxed beef 0.09
Brester & Schroeter (1994)	Beef, Pork, & Chicken	U.S.	Rotterdam	Current & 1-year lag generic and brand advertising	Advertising elasticities -0.005 to 0.03
Duffy (1995)	Pork products	Canada	AIDS	1-year lag generic & brand advertising	Pork 0.006 to 0.101 Product -0.0042 to 0.084
Cranfield (1996)	Beef	U.S. Canada	Linear	Current, own, & cross-advertising; Generic & brand advertising	(w.r.t. beef demand) Canada beef 0.003 Canada pork -0.02 U.S. beef 0.090 U.S. pork -0.227

Several studies have modeled the North American hog and pork market (Martin and Zwart, 1975; Martin, Arthur, and Wilson, 1982; Gilmour and Cluff, 1986; Meilke and Coleman, 1986; Meilke and Scally, 1988; Cluff et. al, 1990; Moschini and Meilke, 1992; Terpstra, 1992; Duffy, 1995). Elasticity estimates from selected studies are shown in Table 3. Some hog supply studies have included research (Huot, Fox and Brinkman, 1988; Voon and Edwards, 1991) and some pork demand studies have included advertising (Duffy, 1995; Brester and Schroeder, 1994; Goddard and Griffith, 1992; Ball and Dewbre, 1989; Hoover, Hayenga, and Johnson, 1992) but none have included both simultaneously to illustrate the trade-offs between the two investment possibilities. Nor have they evaluated the cross-border spillovers that might occur.

Table 3. Elasticity Estimates From Selected Studies of the North American Hog and Pork Market

Study	Period of Analysis	Retail Pork Demand Elasticity	Processor Hog Demand Elasticity	Farm Hog Supply Elasticity
Martin & Zwart (1975)	1962-72	n.a.	Canada -0.47 U.S. -0.37	Western Canada 0.89 Eastern Canada 0.20
Meilke & Coleman (1986)	1961-73	Canada -0.47 U.S. -0.37	n.a.	Western Canada 0.19 Eastern Canada 0.10 U.S. 0.43
Meilke & Scally (1988)	1974-86	Canada -0.84 U.S. -1.19	Canada -2.22 U.S. -1.26	Western Canada 0.07 Eastern Canada 0.06
Moschini & Meilke (1992)	1980-89	Canada -0.294	Canada -0.225	Canada 0.043
Terpstra (1992)	1980-90	Canada -0.44 U.S. -0.89	Canada -0.215 U.S. -0.709	Canada 0.043 U.S. 0.041
Duffy(1995)	1975-92	Canada -0.25 to -1.44 (various pork products)	Canada -0.40	Canada 0.17

The Model

In this section, a two-region model with two market levels is described that represents the Canadian and U.S. hog and pork markets (rest-of-world trade is minor and considered exogenous).

Demand for pork is assumed to be a function of the real prices of pork and its main substitutes (beef and chicken), real disposable income, and pork advertising and promotion. Since advertising and promotion may affect demand in periods beyond the time of expenditure, a variety of lags are attempted. Quarterly dummies are also included to capture consistent seasonal variation in pork consumption. A time trend is included to account for changes in taste over time. Since the North American pork price is largely determined in the bigger U.S. market (the Canadian market is only one-tenth its size), it makes sense to express Canadian demand in quantity-dependent form, and U.S. demand in price-dependent form. Generic advertising is specified in the inverse form to impose diminishing returns (Kinnucan).

Supply of hogs is assumed to be a function of some lagged producer price, a similarly lagged price of corn (the main feed source), and some lagged value of research expenditure. Research variables are included in each country's supply function with a polynomial distributed lag of degree 2. This imposes an inverted "U" shape on the distribution of research effects to reflect gradual adoption and subsequent obsolescence of research. The log of research expenditure is specified. This means that increases in research will impose a proportionally divergent shift, implying research will benefit lower and higher cost producers equally. Because it is divergent, this imposes more conservative producer gains from research compared with parallel and convergent shifts. A lagged dependent variable is included to model Nerlovian adaptive expectations (Nerlove, 1956). It is critical to note that research spillover is not modeled explicitly in this specification. Another hypothesis worth testing in later research is that separate Canadian and U.S. research expenditure levels might affect hog supply in both countries, individually and/or interactively.

Processor demand for hogs is required to link the hog and pork markets. It is assumed to be a function of both the hog and pork prices, a lagged dependent variable, and a time trend. Finally, price-linkage equations are required to relate hog and pork prices across borders. The Canadian pork price is assumed to be a function of the U.S. price (adjusted for tariffs and exchange rate) and a time trend. Similarly, the Canadian hog price is a function of the U.S. hog price and a trend variable.

To estimate these equations as a system, identities must also be specified that relate pork quantities to hog quantities. Hog and pork market-clearing identities are also required to close the model. To summarize, equations are estimated and identities specified as follows:

Canadian demand for pork:

$$\frac{D^C}{POP^C} = a_1 + a_2 RP^C + a_3 P_{bf}^C + a_4 P_{ck}^C + a_5 \frac{1}{ADV_{t-2}^C} + a_6 T + a_7 Y^C \quad (1)$$

U.S. demand for pork:

$$RP^U = b_1 + b_2 \frac{D^U}{POP^U} + b_3 P_{bf}^U + b_4 P_{ck}^U + b_5 RP_{t-1}^U + b_6 \frac{1}{ADV^U} \quad (2)$$

Canadian demand for hogs:

$$H^C = c_1 + c_2 \frac{PP^C}{RP^C} + c_3 H_{t-1}^C + c_4 T \quad (3)$$

U.S. demand for hogs:

$$H^U = d_1 + d_2 PP^U + d_3 H_{t-1}^U + d_4 T \quad (4)$$

Canadian supply of hogs:

$$S^C = e_1 + e_2 PP_{t-5}^C + e_3 PCORN_{t-5}^C + e_4 S_{t-1}^C + e_5 \ln RES_{PDL}^C + e_6 T \quad (5)$$

U.S. supply of hogs:

$$S^U = f_1 + f_2 PP_{t-5}^U + f_3 PCORN_{t-5}^U + f_4 S_{t-1}^U + f_5 \ln RES_{PDL}^U \quad (6)$$

Pork price-linkage equation:

$$RP^C = g_1 + g_2 RP^U + g_3 RP_{t-1}^C + g_4 T \quad (7)$$

Hog price-linkage equation:

$$PP^C = h_1 + h_2 PP^U + h_3 PP_{t-1}^C + h_4 T \quad (8)$$

Canadian hog market clearing:

$$H^C \equiv S^C - X^C \quad (9)$$

U.S. hog market clearing:

$$H^{U} \equiv S^{U} + X^{C} \tag{10}$$

Canadian pork-hog linkage:

$$Q^{C} \equiv H^{C} \cdot CW^{C} \tag{11}$$

U.S. pork-hog linkage:

$$Q^{U} \equiv H^{U} \cdot CW^{U} \tag{12}$$

Canadian pork market clearing:

$$D^{C} \equiv Q^{C} - NT^{CU} - NT^{CR} - \Delta I^{C} \tag{13}$$

U.S. pork market clearing:

$$D^{U} \equiv Q^{U} + NT^{CU} - NT^{UR} - \Delta I^{U} \tag{14}$$

where:

where:	D^C	= pork disappearance in Canada
	POP^C	= Canadian population
	RP^C	= real retail pork price in Canada
	P_{bf}^C	= real retail beef price in Canada
	P_{ck}^C	= real retail chicken price in Canada
	ADV^C	= real per capita pork advertising expenditure in Canada
	T	= time trend variable
	Y^C	= real per capita disposable income in Canada
	RP^U	= real retail pork price in U.S.
	D^U	= pork disappearance in U.S.
	POP^U	= U.S. population
	P_{bf}^U	= real retail beef price in U.S.
	P_{ck}^U	= real retail chicken price in U.S.
	ADV^U	= real per capita pork advertising expenditure in U.S.
	Y^U	= real per capita disposable income in U.S.
	H^C	= Canadian demand for hogs
	PP^C	= real Canadian hog price
	H^U	= U.S. demand for hogs
	PP^U	= real U.S. hog price
	S^C	= Canadian hog production
	$PCORN^C$	= real Canadian corn price
	RES^C	= Canadian swine research expenditure
	RES^U	= U.S. swine research expenditure

S^U	= U.S. hog production
$PCORN^U$	= real U.S. corn price
NT^{CU}	= net trade in pork from Canada to U.S.
X^C	= hog exports from Canada to U.S.
Q^C	= Canadian pork production
CW^C	= carcass weight to hog weight ratio, Canada
Q^U	= U.S. pork production
CW^U	= carcass weight to hog weight ratio, U.S.
NT^{CR}	= net trade in pork from Canada to rest-of-world
I^C	= pork inventories, Canada
NT^{UR}	= net trade in pork from U.S. to rest-of-world
I^U	= pork inventories, U.S.

All variables are current period unless otherwise noted. Quarterly dummy variables (not shown for presentation clarity) are included in each of the equations estimated. Prices and income in the consumer demand equations are deflated by consumer price indices to satisfy the homogeneity condition from demand theory. Similarly, prices on the supply side are deflated by farm input price indices.

Empirical Results

Quarterly data are used. Sample periods were defined according to data availability; most begin in the mid-1970s and end the fourth quarter of 1994. All prices and quantities are from the TROLL data system used by Agriculture Canada, or from the CANSIM database. U.S. prices and quantities are from the USDA/ERS Red Meat Yearbook and Poultry Yearbook. Canadian advertising expenditures are from various issues of provincial and national marketing agency annual reports. U.S. pork advertising data are from Leading National Advertisers publications and represent both generic and brand expenditures. Research expenditure data for 1955-84 are taken from Fox, Brinkman, and Brown-Andison (1987) and are net of recoverable revenues from research stations. These were updated for Canada from Agriculture Canada and for the U.S. from the USDA (personal communication).

Results from estimation of (1) to (8) are presented in Tables 4 and 5. Equations (1), (2), (4), and (8) were corrected for autocorrelation. Goodness-of-fit was good to excellent in all equations, and nearly three-quarters of the 92 estimated parameters were significant at the 10 percent level. Lags of five quarters were found to produce satisfactory results for the producer and feed prices in the supply equations. Lags of 12 to 26 quarters (Canada) and 12 to 21 quarters (U.S.) were used to specify research effects. Results were best when zero endpoints were used in the Canadian equation, but not in the U.S. equation. Such lags are consistent with those found in other livestock research studies (Table 1) and likely represent improvements in nutrition and management (housing, grading, health, and disease control) rather than results from breeding programs, which take longer to produce (Huot, Fox, and Brinkman, 1988).

Advertising was lagged two quarters in the Canadian case, but not for the U.S.

Elasticities are presented in Table 6. Demand for pork was inelastic in Canada but elastic in the U.S., which was consistent with other studies (see Table 3). The elastic nature of U.S. demand may result from the inclusion of the late 70s and early 80s in the sample period. It was more consistent with Meilke and Scally, for example, than with Terpstra. The implications of advertising investment were clearly dependent on own price elasticities of demand so the U.S. demand equation was estimated in both price and quantity-dependent form. Results reported are for price-dependent form. The own price elasticity was estimated to be very similar (-1.2 at the mean) in quantity-dependent form. Beef and chicken appeared to be substitutes for pork, although the chicken estimate was not significant in the Canadian case. Advertising estimates were both significant. Hog demand was inelastic with respect to hog prices -- more so than other studies. Hog supply was highly inelastic in the short run, which conforms to previous results. However, in the long run, the estimates were much more elastic. Corn prices were shown to explain hog supply in both countries. Research was significant at the 10 percent level in both countries.

Simulation Results

The empirical model was extended to a simulation model capable of demonstrating changes in endogenous variables to shocks in certain exogenous variables. The period 1985:1 to 1994:4 was used.

In particular, we focused on a single country--Canada--and examined changes in producer surplus that resulted from single-period and sustained shocks to research and advertising expenditure in both countries. The simulation model was composed of equations (1) to (8) plus identities (9) to (14).

Table 4. Empirical Results: Demand and Supply Equations

Variable	Estimate	*t*-statistic	Variable	estimate	*t*-statistic
(1) Canadian demand for pork (1978:4 — 1994:4) R^2 = .712, D-W = 2.11					
Constant	11.548	4.94	TIME	-0.008	-1.17
Rp^C	-4.120	-5.52	Y^C	-0.975	-0.46
P^c_{bf}	0.025	2.36	DUM1	-0.100	-1.23
P^c_{ck}	0.005	0.34	DUM2	-0.568	-5.87
$1/ADV^C_{t-2}$	-0.295	-2.64	DUM3	-0.263	-2.82
RHO	0.444	3.47			
(2) U.S. demand for pork (1978:1 — 1994:4) R^2 = .975, D-h = 1.62					
Constant	4.129	9.70	$1/ADV^U$	-0.118	-1.61
D^U/POP^U	-0.442	-10.88	Y^U	-0.015	-0.09
P^u_{bf}	0.223	5.32	DUM1	-0.225	-6.47
P^u_{ck}	0.004	2.19	DUM2	-0.334	-8.94
RP^U_{t-1}	0.469	8.42	DUM3	-0.207	-5.67
			RHO	.321	2.37
(3) Canadian demand for hogs (1979:1 — 1994:4) R^2 = .9113, D-h = -1.12					
Constant	1945.34	6.62	DUM1	-25.287	-0.79
PP^C/RP^C	-4.082	-3.76	DUM2	-213.267	-6.15
H^c_{t-1}	0.631	9.32	DUM3	-147.915	-4.56
TIME	-1.390	-0.81			
(4) U.S. demand for hogs (1976:2 — 1994:4) R^2 = .933, D-W = 1.97					
Constant	7399.1	3.42	TIME	-38.22	-5.83
PP^U	-7061.8	-9.04	DUM1	-2924.6	-11.53
RP^U	2012.1	6.75	DUM2	-2009.2	-9.82
H^u_{t-1}	0.746	12.68	DUM3	-2035.5	-9.15
RHO	-0.144	-1.14			
(5) Canadian supply of hogs (1970:2 — 1994:4) R^2 = .978, D-h = -1.56					
Constant	-332.19	-0.91	RES^C_{t-16}	7.851	1.76
PP^C_{t-5}	0.819	1.91	RES^C_{t-17}	8.564	1.76
$PCORN^C_{t-5}$	-145.27	-3.92	RES^C_{t-18}	8.992	1.76
S^c_{t-1}	0.904	20.58	RES^C_{t-19}	9.136	1.76
DUM1	-33.940	-1.06	RES^C_{t-20}	8.992	1.76
DUM2	-242.159	-7.50	RES^C_{t-21}	8.564	1.76
DUM3	-214.382	-6.79	RES^C_{t-22}	7.851	1.76
RES^C_{t-12}	2.141	1.76	RES^C_{t-23}	6.852	1.76
RES^C_{t-13}	4.000	1.76	RES^C_{t-24}	5.567	1.76
RES^C_{t-14}	5.567	1.76	RES^C_{t-25}	4.000	1.76
RES^C_{t-15}	6.852	1.76	RES^C_{t-26}	2.141	1.76
(6) U.S. supply of hogs (1971:2 — 1994:4) R^2 = .839, D-h = -0.10					
Constant	3065.6	0.91	RES^U_{t-14}	565.07	1.72
PP^C_{t-5}	1151.3	2.81	RES^U_{t-15}	568.96	1.70
$PCORN^C_{t-5}$	-494.832	-2.55	RES^U_{t-16}	480.61	1.76
S^c_{t-1}	0.835	15.75	RES^U_{t-17}	300.02	1.87
DUM1	-3184.2	-11.46	RES^U_{t-18}	27.20	0.82
DUM2	-2458.5	-9.57	RES^U_{t-19}	-337.85	-1.40
DUM3	-2724.6	-10.71	RES^U_{t-20}	-795.14	-1.52
RES^U_{t-12}	280.59	1.68	RES^U_{t-21}	-1344.67	-1.56
RES^U_{t-13}	468.95	1.69			

Table 5. Empirical Results: Price-Linkage Equations

Variable	Estimate	*t*-statistic	Variable	estimate	*t*-statistic
(7) Pork price-linkage (1977:1 — 1994:4) R^2 = .880, D-h = 3.08					
Constant	0.051	0.56	DUM1	-0.007	-0.56
Rp^U	0.043	3.06	DUM2	-0.002	-0.19
RP^C_{t-1}	0.740	10.67	DUM3	0.054	4.02
TIME	-0.000	-0.22			
(8) Hog price-linkage (1977:2 — 1994:4) R^2 = .811, D-W = 2.16					
Constant	82.163	3.28	DUM1	-4.713	-2.53
PP^U	81.044	10.78	DUM2	-1.516	-0.70
TIME	-0.992	-4.16	DUM3	0.367	0.18
PP^C_{t-1}	0.088	1.17	RHO	0.767	8.86

Table 6. Selected Elasticities

Elasticity	Canada	United States
Canadian pork demand w.r.t.		
Pork price	-0.538**	-0.738**
Beef price	0.258**	0.371**
Chicken price	0.048	0.114**
Income	-0.124	-0.101*
Advertising	0.027**	0.005*
Hog demand w.r.t.		
Hog price (short run)	-0.135**	-0.342**
Hog price (long run)	-0.366**	-1.352**
Pork price (short run)	0.135**	0.440**
Pork price (long run)	0.366**	1.735**
Hog supply w.r.t.		
Hog price (short run)	0.040*	0.065**
Hog price (long run)	0.418*	0.394**
Corn price (short run)	-0.061**	-0.067**
Corn price (long run)	-0.637**	-0.406**
Research (short run)	0.031*	0.011*
Research (long run)	0.324*	0.066*

Notes: *Significant at the 10 percent level. **Significant at the 5 percent level.
Figures for U.S. pork demand are flexibilities.

Additional identities formulated two measures of Canadian producer surplus corresponding to farm and retail levels. Calculation of producer surplus was problematic when supply was not explained by current price, PP_t, but by price in periods $t\text{-}5$ (surplus measures depicted in Figure 1 assumed that price and quantity were measured in the same period).

This problem can be overcome conceptually and empirically with a Nerlovian adaptive price expectations formulation used in the estimation of the equation. Accordingly, quantity in period t is a result of the *expected* price in period t, EP_t, which is some function of past prices. Each period, hog farmers revise the price they expect to prevail in the coming period in proportion to the error they made in predicting price in the current period. The speed of this adjustment may be estimated as θ, where $1\text{-}\theta$ is the coefficient on the lagged dependent variable in the supply equation. If the lag is five periods, EP_t is specified as:

$$EP_t = \theta \cdot P_{t-5} + \theta(1-\theta) \cdot P_{t-6} + \theta(1-\theta)^2 \cdot P_{t-7} + \theta(1-\theta)^3 \cdot P_{t-8} + \ldots \tag{15}$$

The supply equation may now be expressed as a function of a single (expected) price in period t that combines information from both lagged price and the lagged dependent variable. Producer surplus, PS, may now be defined as the area above the supply curve, $MC(Q)$, and below an expected price, EP_0. This is equivalent to the revenue less the integral of the supply curve up to quantity Q_0 less any (fixed) research or advertising costs (where the research investment does not include investment by government but only additional moneys invested by producer groups):

$$PS = EP_0 \cdot Q_0 - \int_0^{Q_0} MC(Q)dQ - RES - ADV \tag{16}$$

A final modification must be made due to the presence of lagged research, advertising, and lagged dependent variables, which mean that benefits and costs of investment in period t are felt in successive years. These future values are discounted by a discount rate, r, to calculate the net present value of expected producer surplus:

$$PS_{NPV} = \sum_{t=1}^{i} [\frac{EP_t \cdot Q_t}{(1+r)^t} - C(Q_t, RES_t) - RES_t - A \tag{17}$$

A discount rate of 5 percent was chosen. In addition, producer surplus measures were adjusted for inflation and presented hereafter in 1985 Canadian dollars.

The simulation model is validated in Table 7 with correlation coefficients, percentage root-mean-square error, and error due to bias. These statistics indicate that, in general, the simulation model tracks actual values reasonably well and is suitable for further analysis.

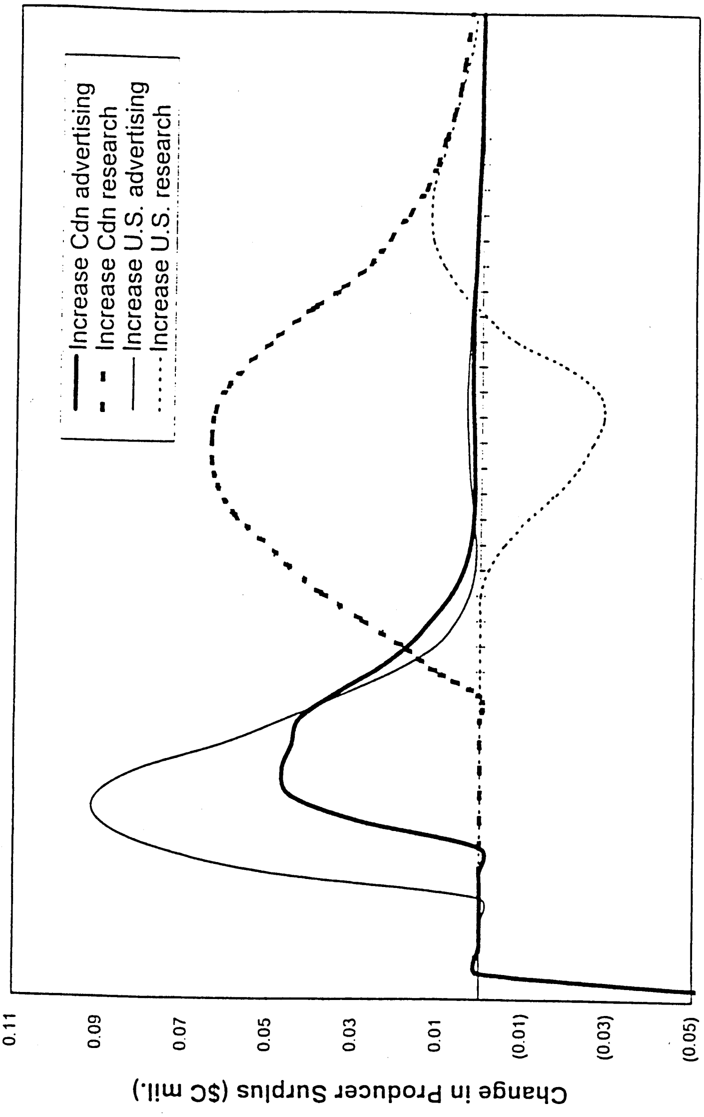
Table 7. Validation Statistics for the Simulation Model

Endogenous Variable	Correlation Coefficient	Percent Root-Mean-Square Error	Theil Fraction of Error Due to Bias
D^C	0.63	5.45	0.002
D^U	0.71	5.29	0.002
S^C	0.90	3.71	0.094
S^U	0.69	5.48	0.004
H^C	0.90	3.22	0.182
H^U	0.69	5.66	0.000
PP^C	0.89	13.09	0.063
PP^U	0.76	14.22	0.002
RP^C	0.51	7.22	0.002
RP^U	0.70	6.28	0.001
Q^C	0.93	3.23	0.180
Q^U	0.79	5.65	0.000
NT	0.73	26.63	0.146
X	0.36	14.72	0.080
$FARMPS^C$	0.80	12.93	0.019
$RETAILPS^C$	0.40	7.69	0.066

Notes: NT is net trade in pork between Canada and the U.S. X is hog exports from Canada to the U.S. FARMPS is farm-level producer surplus. RETAILPS is retail-level producer surplus.

Single period shocks: The first scenario simulates an increase of C$100,000 in Canadian advertising or research. Figure 2 shows the change in pork producer surplus over the simulated period assuming the increase takes place only in 1985:1. The graph also shows what would happen if identical amounts went to advertising and research in the United States. The critical assumption here is that U.S. advertisers or U.S. or Canadian researchers would *not* react to this "donation" by reducing their expenditure.

Figure 2. Simulated results from single-period shocks



An increase in Canadian advertising results in a supply response seven periods hence (recall that advertising is lagged two quarters and supply is lagged five quarters). The impact of this increase is seen to approach zero three years from the initial impact. The impact of a shock to Canadian research is felt later than that for advertising, and lasts longer. Interestingly, results suggest that Canadian producers would be better off giving C $100,000 to the U.S. generic advertising campaign, even though the advertising elasticity for the U.S. is lower. This is a reflection of a consumption response in a much larger market, from which prices are transmitted to Canada. Not surprisingly, Canadian producers lose from financing U.S. hog research. However, such losses are offset somewhat by a supply response (the "Cobweb effect") two years later as U.S. producers react to a lower price.

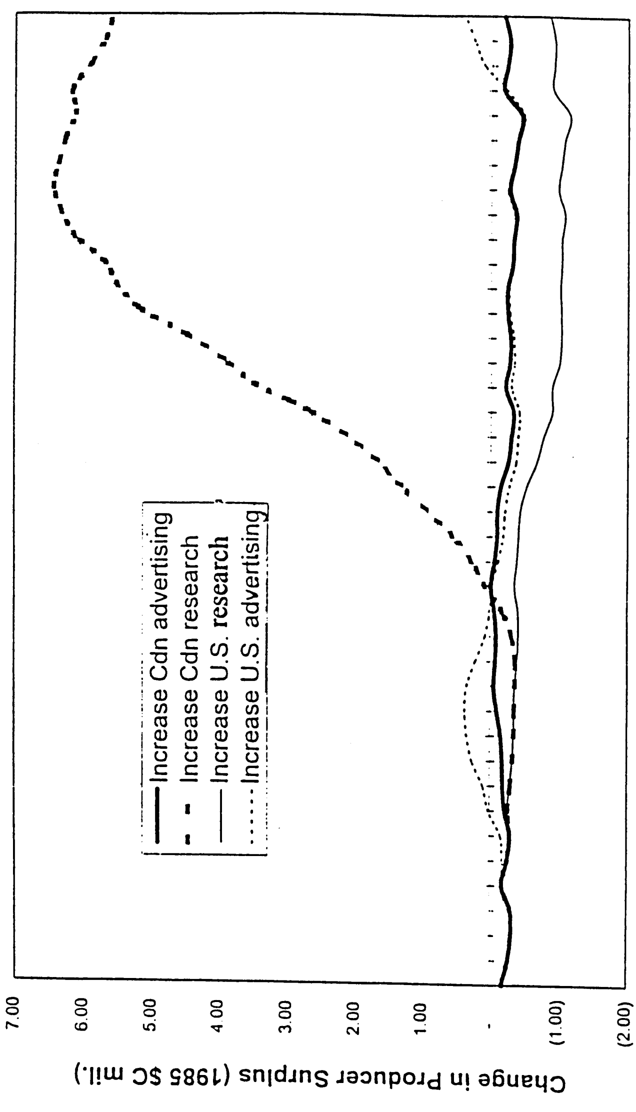
Sustained shocks: This simulation is similar except that an infusion of money equal to 50 percent of Canadian actual advertising expenditure is applied in *each* quarter across the simulation period. Results differ substantially. Only Canadian research generates sustained net gains at this level. U.S. research increases results in losses of Canadian producer surplus. Due to the cumulative effect of advertising and diminishing returns, advertising impact is unable to cover its costs, and results in losses when considered throughout the period (although there appear to be short-term gains from advertising in the U.S.). To summarize the simulations, Table 8 shows changes in producer surplus (equivalent to the integrals under the curves in Figures 2 and 3) and associated benefit-cost ratios for each scenario.

Table 8. Summary of Simulation Results

	Shocked Variable	Change in Producer Surplus (1985 $C million)	Benefit-Cost Ratio
One-period Increase	Canadian advertising	0.237	2.37
	Canadian research	0.770	7.70
	U.S. advertising	0.612	6.12
	U.S. research	-0.078	-0.78
Sustained Increase	Canadian advertising	-8.66	-2.17
	Canadian research	94.50	23.62
	U.S. advertising	-5.12	-1.28
	U.S. research	-25.4	-6.35

Negative returns in the sustained scenario raise the question of whether Canada may be investing excessively in pork advertising. To investigate this, Canadian advertising expenditure was, in turn, increased and decreased by 10 percent in two additional simulations. In both cases, there was a reduction in producer surplus. This suggests that Canadian advertising is fairly close to optimal levels over this period as a whole.

Figure 3. Simulated results from sustained shocks



Conclusions

Funds from checkoff schemes in the hog and pork industry may be allocated to either research or advertising, and both options should be considered simultaneously. Results from this study suggest that there are large net returns to Canadian hog research, thus supporting findings of similar studies and studies of livestock research in general. There are more modest gains to Canadian generic advertising, and the possibility of spending too much.

This study has also indicated the more unusual -- and perhaps politically impractical -- possibility of funding advertising in another country (although coffee and tea producing countries, for example, have pursued this strategy successfully for years). Such results point to the inherent dangers of modeling single markets in isolation.

Further research could extend the simulation results to evaluate options from the point of view of U.S. producers. Use of alternative functional forms, particularly with respect to research, would likely produce different results. In addition, optimal expenditures could be determined explicitly by incorporating optimal rules into the simulation model.

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