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Oswald E.R. Zachariah, Glenn Fox
and
George L. Brinkman

UNIVERSITY of GUELPH

Department of Agricultural Economics and Business

University of Guelph
Guelph, Ontario
Canada
N1G 2W1

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* The authors are respectively a former research assistant, an assistant professor and a professor in the Department of Agricultural Economics and Business, University of Guelph.

Abstract

The economic returns to Canadian federal broiler chicken research between 1968 and 1984 were estimated using the economic surplus approach. The impact of distortions in the product market and of the excess burden of taxes on the net benefits of research and the distribution of gross benefits between producers and consumers were assessed. Rates of return to research investments over this period were estimated to be between 48% and 63%. All of the benefits of this research have accrued to consumers, and producers have actually been made worse off by broiler research under the existing regime of supply management.

I. Introduction

Estimates of the rate of return to public research on crops and estimates of benefits from overall agricultural research systems have been found to be high (see Carter et al. (1984), Evenson (1984) and Ruttan (1982)). Estimated rates of return to Canadian agricultural research that have been reported in the literature are comparable to rates of return observed in other countries. Table 1 summarizes the results of several studies conducted in Canada. At present, little is known about the rate of returns to livestock research. High rates of return to public research at the margin are indicative of inadequate levels of research funding. Variation in rates of return across commodities within a single country suggest that the allocation of research support among commodity research programs is inefficient. The present lack of information on rates of return to Canadian livestock research makes evaluation of the efficiency of funding allocation patterns problematic. In providing an estimate of the rate of return to broiler research in Canada, this paper and companion studies (see Widmer et al. (1988), Fox et al. (1987), Haque et al. (1987)) seek to address this information need.

Markets for farm products are frequently distorted by public policies. This is particularly true for poultry products and milk in Canada. The extent to which economic benefits are generated by agricultural research and the distribution of those benefits among various sectors of the economy depend on the nature of this intervention. Studies which have estimated rates of return to agricultural research have, for the most part, ignored the effect of product market distortions. This paper explicitly incorporates the structure of the supply

Table 1: Rates of Return to Agricultural Research in Canada

Authors	Commodities	Time Period	Approach	Rate of Return
Nagy and Furtan (1977)	Rapeseed	1960-1976	Economic Surplus	95-110%
Prentice and Brinkman (1982)	Agricultural Research and Extension in Ontario	1950-1972	Value of Inputs Saved	64.7-67.7%
Farrell, Funk and Brinkman (1984)	Biotechnology Research on Corn, Wheat, Barley and Canola	1984-2003	Delphi	14.6-40.8%
Ulrich, Furtan and Downey (1984)	Rapeseed	1951-1982	Economic Surplus	51%
Zentner and Peterson (1984)	Wheat	1946-1979	Economic Surplus	30-39%
Ulrich and Furtan (1985)	Wheat	1951-1983	Economic Surplus	28%
	Barley	1951-1983	Economic Surplus	22%
	Rapeseed	1951-1983	Economic Surplus	50%
	Forage	1954-1983	Economic Surplus	14%

management system[1] used to regulate output in the broiler chicken industry in Canada in the estimates of gross research benefits. The sensitivity of estimated net research benefits to the marginal excess burden of tax collection is also examined. Fox (1985) has argued that failure to include the marginal excess burden as a cost of research has introduced a systematic upward bias in previous rate of return estimates.

II. Measuring Research Benefits Under Supply Management

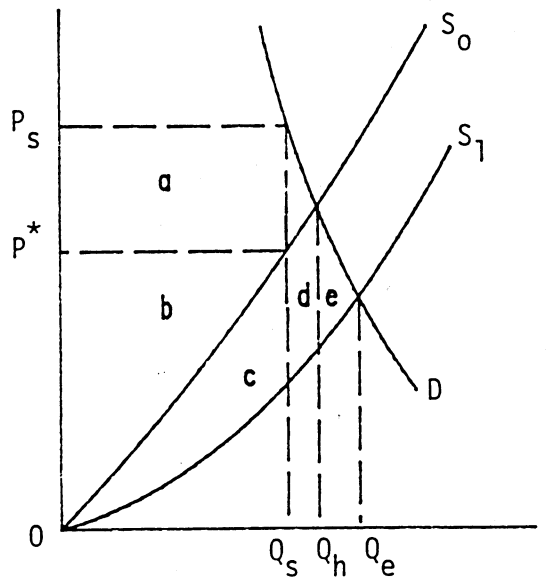
This study uses the economic surplus approach[2] to measure the gross benefits of broiler research. This approach calculates research benefits as the gain in consumers' surplus plus the net change in producers' surplus as research generates new technology which shifts the industry supply function down and to the right. This characterization of the adjustment to new technology implicitly assumes that the product price is a market clearing price determined by the intersection of supply and demand. Under supply management, however, the role of demand and supply in the determination of product price is abrogated. Price is determined by a "cost of production" formula and a national quota is established which restricts total production to the level of expected domestic demand when consumers face this administratively determined price. This national quota was distributed among provinces and subsequently among individual producers based on historical market shares when the scheme was implemented. Quotas are enforced using a two price mechanism, where over quota production receives a much lower price than production within quota.

Figure 1 illustrates the impact of supply management on the calculation of research benefits with the economic surplus model. In Figure

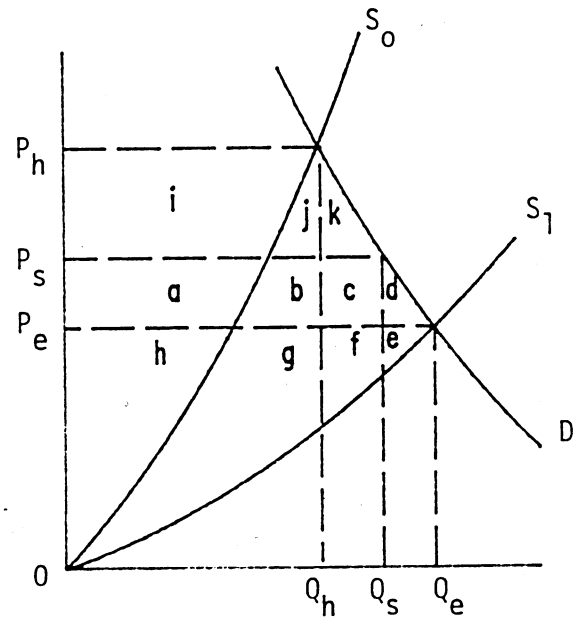
Figure 1

Broiler Research
Benefits Under Supply Management

(A)



(B)



1(A), the administered price, P_s, is maintained by imposing a quota at Q_s. S_1 is the actual supply function and S_0 is a hypothetical relationship that would exist if research had not been undertaken. In the absence of supply management, a research induced shift in the supply function from S_0 to S_1 would increase the market clearing equilibrium output from Q_h to Q_e, and the net change in consumers' and producers' surpluses would be the area c+d+e. Under supply management, consumers' surplus remains unchanged because research does not lead to a reduction in P_s.[3] Producers' surplus, however, increases from a+b to a+b+c. The gross gain generated by research, then, is the area c. The area d+e is the additional gain that would have been generated by research if supply management had not been in place.

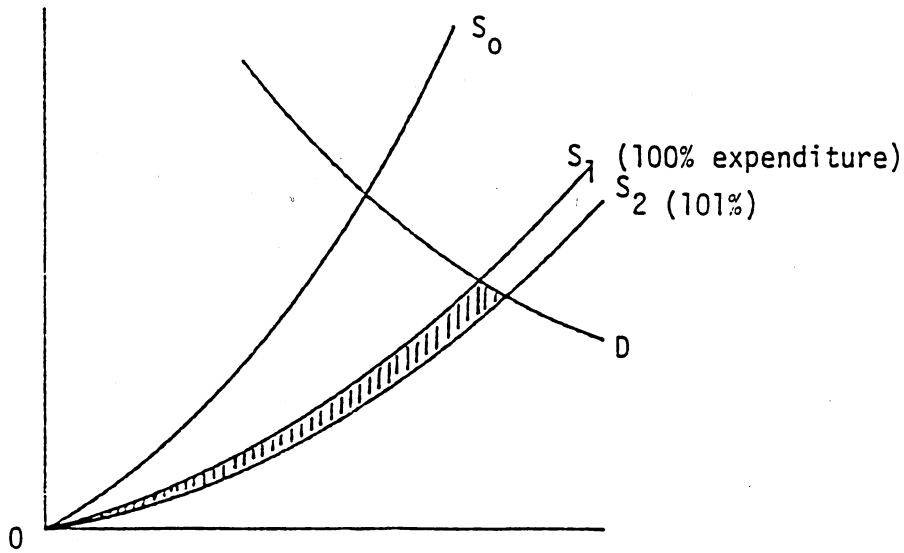
It is conceivable, and in fact this situation arises in certain years in this study, that the supply function that would have existed in the absence of research would intersect domestic demand above the formula price P_s. This use is illustrated in Figure 1(B). Hence, research does increase consumers' welfare as $P_h > P_s$. Consumers' surplus increases by the area i+j+k. Producers' surplus would have been the area i+a+h in the absence of research, and becomes a+h+b+c+g+f when S_1 is the supply function. The gross gain from research is therefore the area j+k+b+c+g+f. Once again the area d+e is the unrealized gross benefit of research.

The existence of potential but unrealized benefits from research has important implications for agricultural research policy. Efficient allocation of research funding across commodities requires that rates of return be equated at the margin. Research on supply managed commodities, however, is penalized relative to research on commodities sold under

more competitive conditions. In order to facilitate cross-commodity rate of return comparisons, three sets of estimates of research benefits are presented in this paper. The first set represents the benefits that actually occur under the present supply management scheme. A second set of estimates show what the research benefit would have been if production quotas had not been in place, but imports of broilers remained restricted, so that product price was determined by the intersection of domestic supply and demand. A third set of estimates shows what the benefits of research would be if neither production quotas nor import restrictions were in place, and the Canadian industry operated in an integrated north american market.

It is the rate of return to changes in research funding at the margin that is of interest in evaluating the efficiency of research resource allocation. Traditionally, the economic surplus model has been implemented using an index number approach (see Peterson (1967), Ayer and Schuh (1972)). In this study, the supply function for broilers is estimated econometrically and lagged research and extension expenditures are included as arguments of the estimated function. Simulations are performed in which the historical level of research expenditure is increased by 1%, resulting in a small shift in the supply function (Figure 2). The gross benefits generated by this shift are compared to the dollar value of the 1% increase in funding to obtain estimates of net benefits at the margin. These sets of estimates are reported for marginal benefits, corresponding to the three sets of estimates of total or average benefits.

Figure 2 Marginal Research Benefits



III. The Estimated Supply Function

Estimates of the coefficients of the supply function are reported in Table 2. Lindner and Jarrett (1978) have argued that the type of shift induced in the supply function by research can have an important impact on the value of research benefits. Two functional forms for the supply function were compared in this study, each representing a different type of supply shift. A linear supply function (equation 1) gives a parallel shift, and a partial-logarithm function (equation 2) gives a pivotal proportional shift.[4]

$$Q_t^s = a + \sum_{i=1}^{I} b_i P_i + \sum_{j=1}^{I} c_j X_j \qquad (1)$$

$$Q_t^s = a \prod_{i=1}^{I} P_i^{b_i} \; e^{\sum_{j=1}^{J} c_j X_j} \qquad (2)$$

Q_t^s denotes quantity supplied, the P's are prices of inputs or output and the X's are non-price variables such as research expenditure which may be lagged. The c's, b's and a are parameters and e is the base of natural logarithms. A partial logarithmic function was selected on the basis of goodness of fit and the sign and significance of individual coefficients. Ordinary Least Squares was used as the estimator since all of the regressors are predetermined or exogenous. Annual data was used.[5] Output data was obtained from Production of Poultry and Eggs (Statistics Canada, Cat. 23-204). A marginal cost price is needed as a regressor in the supply equation. Observed farm gate prices for broilers in Canada are not marginal cost prices, since they include rental costs of quota. Since data on quota prices are not available, a marginal cost price cannot be computed from observed price data. As a compromise, U.S.

Table 2: The Broiler Supply Function

Dependent Variable: Canadian Supply of Broiler Meat
(million kg. of dressed broilers, eviscerated weight)
Functional Form: Partial-Logarithmic
Sample: 1964-1984, Annual Data

Explanatory Variable	Coefficient	t-Statistic	Elasticity
Constant	3.2758	4.0340	
Logarithm of Output Price (t-1)	0.2987	2.2235	0.2987
Logarithm of Price of Mash (t-1)	-0.7748	-5.2615	0.7748
Logarithm of End of Year Stock of Broiler Meat (t-1)	-0.0093978	-2.1808	
Provincial Research and Extension (t-1)	0.0613	2.5289	
Education Index (t)	0.0357	5.4157	
Canadian Federal Research			
t-4	0.00809	1.95347	0.0177
t-5	0.01416	1.95347	0.0310
t-6	0.01820	1.95347	0.0398
t-7	0.02022	1.95347	0.0442
t-8	0.02022	1.95347	0.0442
t-9	0.01820	1.95347	0.0398
t-10	0.01416	1.95347	0.0310
t-11	0.00809	1.05347	0.0177
sum	0.12134	1.95437	1.2653
U.S. Research			
t-5	0.0000066	0.0056	
t-6	0.0000120	0.0056	
t-7	0.0000160	0.0056	
t-8	0.0000180	0.0056	
t-9	0.0000200	0.0056	
t-10	0.0000200	0.0056	
t-11	0.0000180	0.0056	
t-12	0.0000160	0.0056	
t-13	0.0000120	0.0056	
t-14	0.0000066	0.0056	
sum	0.0001500	0.0056	
Provincial Supply Management Dummy Variable	-0.1936138	3.5338	

Adjusted R^2: 0.97155
Durbin-Watson: 2.19581
F-Statistic: 86.36841

broiler prices were used as the basis for the construction of a Canadian marginal cost price. Given the relatively free movement of inputs and technology across the border, and the unregulated nature of U.S. broiler production, it is expected that U.S. prices should correspond closely to Canadian marginal cost prices. U.S. prices were converted to Canadian dollar equivalent prices using the annual average exchange rate. The price of growing mash was obtained from Consumer and Statistics Canada data. The stock of broiler meat was obtained from Production of Poultry and Eggs.

Estimates of total provincial expenditures on agricultural research were obtained from budget documents of the provincial governments. Research components of the budgets of each provincial Ministry of Agriculture were identified. Allocation of total research expenditure among the specific commodities was based on the provincial distribution of man-years by commodity reported by the Canadian Agricultural Research Council.

Total provincial extension expenditures were also taken from the relevant components of provincial budget documents. Allocation by commodity was performed on the basis of the share of annual gross sales that the commodity generated as a proportion of gross sales of the total farm sector in each year. The rationale for this approach is that provincial Ministries of Agriculture focus extension efforts on those agricultural industries with the greatest economic significance for the province.

The level of human capital invested in the farm sector can play a significant role in the successful adoption of new technology at the farm level. In this study, an index of years of formal education

received by farmers was used to measure the human capital of the farm sector. The specific index used was developed by Hunt (1984) and updated for this study using census data.

Procedures used to estimate the annual costs of the Animal Productivity Research Program are reported in detail in Fox et al. (1987). Research expenditures include direct Animal Productivity Research expenditures adjusted to include operating costs, employee benefits, capital and grants, and a prorated share of administration and support. In addition, Public Works expenditures for livestock facilities in the national capital region are included along with relevant disease research activities of the Animal Pathology Division of Agriculture Canada. These latter activities are highly complementary to the thrust of the Animal Productivity Research Program, and so they needed to be added to the overall costs. These costs were added together to construct the Canadian Federal research variable.

Estimates of livestock research investments by the federal and state governments in the United States were obtained from Schultz (1953), the U.S. House of Representatives Department of Agriculture Appropriations hearings (various years) and from the Current Research Inventory System (CRIS) of the USDA. Annual research expenditures at the state and federal level for broilers is available from 1968 to 1983 from the CRIS data. Schultz reported the distributions of total livestock research by commodity for 1951. A similar distribution for the year 1959 was obtained from the House of Representatives Appropriations hearings. Total livestock research estimates for 1952-1958 and 1960-1967 were obtained from the appropriations hearings and the distribution by commodity was obtained by linear interpolation using data from 1951,

1959 and 1968. Historically, there has been a close relationship between U.S. agricultural research budgets from year to year, which would suggest that linear interpolation should provide a reasonable approximation of actual expenditure patterns. The dummy variable captures the effect of Quebec entering the national supply management scheme in 1972.

Estimation of the length and degree of the lag structure for the research variables followed procedures introduced by Cline (1975). A second degree polynomial was identified for Canadian federal research. The hypothesis of zero end-point constraints on the Canadian research lag was not rejected at the 1% level (see Meilke, 1975). U.S. research was not found to have a statistically significant impact on the Canadian broiler supply function. All other coefficients in the equation have the expected signs and are significant. The elasticity of supply with respect to ouput price is 0.2987. The long run elasticity of output with respect to federal research is 0.2653 indicating that a 1% change in federal expenditure, the supply function would shift by 0.2653%.

IV. Calculation of Research Benefits

Research benefits were calculated on an annual basis for the years 1972 to 1995. The focus of this investigation was on federal research expenditures made between 1968 and 1984. The lag structure of the supply function reported in Table 2 indicates that research undertaken between 1968 and 1984 would have its first impact on the national supply function in 1972 and no impact after 1995.

For the years in which the domestic supply function without research (S_0) intersects domestic demand above the formula price, it is necessary

to have an estimate of the elasticity of the domestic demand function. Since the supply function is a farm-level relationship, a derived farm level demand function for broiler meat is required. A marketing margin equation was estimated and used to derive a farm level elasticity of demand from the retail demand elasticity of -0.6551 reported by Hassan and Johnson (1979). The procedure follows Tomek and Robinson (1981). The relationship between the marketing margin for broilers and the retail price can be represented by a marketing margin equation:

$$M = c + a(P_r) \qquad (1)$$

where, $M = P_r - P_f$, is the marketing margin,

P_r is the retail price of broilers,

P_f is the farm price of broilers,

and a and c are parameters.

A marketing margin equation was estimated for the period 1955-1984. It yielded the following results:

$$M = \underset{(3.766)}{48.289} + \underset{(8.245)}{0.437}\ P_r \qquad (2)$$

$R^2 = 0.71$

t-statistics are in parentheses.

The farm level elasticity of demand for broilers is therefore:

$$E_f^d = E_r^d \{1-[c/(1-a)\bar{P}_r]\} \qquad (3)$$

where, E_f^d is the farm level demand elasticity

E_r^d is the retail demand elasticity

$\bar{P}_r$ is the average retail price (1955-1984)

and c and a are coefficients from equation 1.

The resulting farm level elasticity of demand is -0.4736. The derived demand function was assumed to be of a constant elasticity form.

Federal livestock research installations generate revenues from the sale of livestock and livestock products from herds and flocks maintained for research purposes. These funds (called recoverable revenues) are remitted directly to the federal treasury. Consequently, the budgeting allocations to support research activities are larger than the net treasury cost. Nevertheless, it is the budget allocation that determines the size of the research effort and presumably therefore the rate of technological change. To reflect this institutional facet of the Canadian agricultural research system, budgeted research costs are used as the explanatory variable in estimating the supply function. Calculation of net benefits, however, uses budget allocations less recoverable revenues as the net treasury cost.

Annual values of the gross benefits of research are reported in Table 3. These values were obtained by integration using the supply functions, the derived demand function, the formula price and the national quota. Several formulas have been proposed (see Peterson (1967), Akino and Hayami (1975)) as approximations for relevant measures of gross research benefits using the economic surplus approach. This study uses integration with the relevant estimated functions and observed prices and quantities to obtain exact measures of the changes in consumers' and producers' surpluses. S_0 for each year was obtained by setting Canadian federal broiler research expenditure in the years 1968 to 1984 at zero. S_1 was obtained by substituting the actual research expenditure for each of those years. The realized benefits correspond to the benefits derived under the existing supply management system. The closed economy benefit measure what the impact of research would have been in the absence of a domestic quota when a closed border is main-

Table 3: Gross Annual Research Benefits From Federal Broiler Research, Conducted Between 1968 and 1984

(Million 1981 dollars)

Year	Realized	Closed Economy	Open Economy
1972	4.3	5.2	3.3
1973	14.9	21.5	19.1
1974	38.2	38.6	20.3
1975	42.3	45.0	31.2
1976	70.4	70.6	36.1
1977	81.9	83.4	45.3
1978	96.2	97.8	55.1
1979	124.6	124.9	56.8
1980	113.8	114.6	53.4
1981	125.3	127.4	50.8
1982	114.6	115.7	49.8
1983	108.4	109.1	47.1
1984	111.4	113.8	48.2
1985	112.7	114.4	47.5
1986	101.1	102.8	43.7
1987	89.0	90.6	39.6
1988	79.8	81.4	36.3
1989	68.4	70.1	32.1
1990	56.9	58.6	27.6
1991	44.6	46.3	22.4
1992	32.8	34.5	17.2
1993	21.1	22.7	11.7
1994	10.8	12.2	6.4
1995	3.8	4.4	2.4

tained. The open economy benefits correspond to the hypothetical situation of an open border with the United States using the U.S. price for broilers. Benefits beyond 1984 were obtained by projecting explanatory variables in the supply function into the future at their 1984 values.

The distribution of benefits among consumers and producers is reported in Table 4. The relatively inelastic domestic demand function results in a net loss in producers' surplus from research in every year of the closed economy simulation and in many years of the realized benefit scenario. In the open economy simulation, producers gain 100% of total benefits because of the assumption of a perfectly elastic price facing Canadian suppliers in an integrated north american market. This assumption is based on the small share of total north american output that is produced in Canada. Present values of gross benefits are reported in Table 5.

The estimated net benefits of Canadian federal broiler research are reported in Table 6. The average rate of return estimates range from 50.7% to 62.5% across the three market structure simulations. More germaine to the efficiency of resource allocation in public agricultural research, rates of return at the margin range from 51.9% to 60.2%. These compare favourably to the rates of return to Canadian crop research reported in Table 1 and in fact dominate the estimated rates of return to biotechnology research in corn, wheat, barley and canola reported by Farrell et al. (1984) and the returns to crop breeding in wheat, barley and forages reported by Ulrich and Furtan (1984).

When research costs are arbitrarily increased by 20%[6] to test the sensitivity of their results to recognition of the marginal excess

Table 4: Distribution of Gross Annual Benefits of Canadian Federal Broiler Research Conducted Between 1968 and 1984

(million 1981 dollars)

Year	Consumer Gains			Producer Gains		
	Realized	Closed Economy	Open Economy	Realized	Closed Economy	Open Economy
1972	0.0	8.7	0.0	4.3	-3.5	3.3
1973	0.0	36.1	0.0	14.9	-14.6	19.1
1974	46.6	64.9	0.0	-8.4	-26.3	20.3
1975	34.1	75.6	0.0	8.2	-30.7	31.2
1976	108.9	118.7	0.0	-38.4	-48.1	36.1
1977	110.0	140.3	0.0	-28.1	-56.9	45.3
1978	132.0	164.5	0.0	-35.8	-66.7	55.1
1979	194.9	210.0	0.0	-70.4	-85.1	56.8
1980	170.2	192.7	0.0	-56.3	-78.1	53.4
1981	174.1	214.3	0.0	-48.9	-86.8	50.8
1982	167.0	194.6	0.0	-52.4	-78.9	49.8
1983	162.1	183.4	0.0	-53.8	-74.4	47.1
1984	150.1	191.3	0.0	-38.6	-77.6	48.2
1985	157.6	192.3	0.0	-44.9	-77.9	47.5
1986	138.2	172.8	0.0	-37.1	-70.0	43.7
1987	117.8	152.4	0.0	-28.8	-61.8	39.6
1988	102.3	136.9	0.0	-22.5	-55.5	36.3
1989	83.2	117.9	0.0	-14.8	-47.8	32.1
1990	63.9	98.6	0.0	-7.0	-39.9	27.6
1991	43.2	77.8	0.0	1.4	-31.6	22.4
1992	23.4	58.0	0.0	9.5	-23.5	17.2
1993	3.6	38.2	0.0	17.5	-15.5	11.7
1994	0.0	20.5	0.0	10.8	-8.3	6.4
1995	0.0	7.4	0.0	3.8	-3.0	2.4

Table 5: The Present Value of Gross Research Benefits

(millions of $1981)

	Gross Benefits	Producer Gains	%	Consumer Gains	%
Present Value of Benefits (discount rate = 2%)					
Realized	1224.8	-388.4	-31.7	1613.2	131.7
Closed Economy	1618.2	-933.2	-57.7	2551.4	157.7
Open Economy	594.7	594.7	100.0	0.0	0.0
Present Value of Benefits (discount rate = 5%)					
Realized	792.8	-256.9	-32.4	1049.7	132.4
Closed Economy	811.7	-553.2	-68.2	1364.9	168.2
Open Economy	390.3	390.3	100.0	0.0	0.0
Present Value of Benefits (discount rate = 10%)					
Realized	410.3	-133.1	-32.4	543.3	132.4
Closed Economy	421.0	-286.9	-68.2	707.9	168.2
Open Economy	207.5	207.5	100.0	0.0	0.0

Note: 1. All present values have been discounted to base year 1968.

2. Discount rates are real discount rates since all monetary values have been expressed in constant 1981 dollars.

Table 6: Net Benefits of Canadian Federal Broiler Research Conducted Between 1968 and 1984

Benefit Measurement	Market Scenario		
	Supply Management	Closed Economy	Open Economy
Average Returns:			
Net present value of benefits	763.3	782.2	360.8
Benefit/cost ratio	26.9	27.5	13.2
Internal rate of return	60.6	62.5	50.7
Marginal Returns:			
Net present value of benefits	6.0	7.1	4.2
Benefit/cost ratio	20.7	24.3	14.7
Internal rate of return	56.0	60.2	51.9

Notes:
1. All monetary values are in million constant 1981 dollars.
2. All present values have been discounted the base year 1968.
3. Net present values and Benefit/Cost ratios are reported for a 5% real discount rate.

burden of taxation, estimates of net benefits fall only slightly (Table 7). Public finance specialists have not yet been able to agree on an appropriate value of the marginal excess burden, but it would appear that even extremely high values would be needed to appreciably depress the rate of return to broiler research.

V. Discussion

The results of this analysis show that the level of investment in broiler research in Canada has been inadequate. Furthermore, rates of return to broiler research are higher than many of the estimated rates of return to Canadian research on selected crops. The existence of distortions in the product market for broilers does not appear to have depressed rates of return to broiler research, but the mechanism used to determine the price in that market has a profound effect on the distribution of benefits among producers and consumers.

Table 7: Sensitivity of Net Benefits to the Marginal Excess Burden of Taxes

Benefit Measurement	Market Scenario		
	Supply Management	Closed Economy	Open Economy
Average Returns:			
Net present value of benefits	757.4	776.3	394.1
Benefit/cost ratio	22.4	23.0	11.0
Internal rate of return	56.6	58.3	46.6
Marginal Returns:			
Net present value of benefits	5.9	7.0	4.1
Benefit/cost ratio	17.2	20.2	12.3
Internal rate of return	52.0	56.0	47.9

Notes:
1. All monetary values are in million constant 1981 dollars.
2. All present values have been discounted the base year 1968.
3. Net present values and Benefit/Cost ratios are reported for a 5% real discount rate.

Footnotes

1. See Arcus (1981), Veeman (1982) and Holliday and Martin (1977) for further discussion of the supply management system for broilers.

2 See Brinkman (1983) for a summary of the various approaches that have been used to measure research benefits.

3 In fact, procedures used to determine P_S could be influenced by changing technology. In the case of broilers, however, the technical input/output coefficients used to estimate production costs are updated relatively infrequently and adjustments are reflected in P_S only after a considerable time lag. The effects of these adjustments on consumer welfare are expected to be small and are ignored in this analysis.

4 These shift types were identified as most appropriate by Lindner and Jarrett.

5 Data used to estimate this function is available in Fox et al. (1987) and is also available from the authors on request.

6 See, for example Browning (1976), Stewart (1984), Ballard et al. (1985) and Browning (1987).

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