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Lorne Widmer, Glenn Fox
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UNIVERSITY of GUELPH

**Department of Agricultural Economics and Business**

University of Guelph
Guelph, Ontario
Canada
N1G 2W1

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** Lorne Widmer is a graduate research assistant, Glenn Fox is an assistant professor and George Brinkman is a professor in the Department of Agricultural Economics and Business, University of Guelph.

## Abstract

The net social benefits of Canadian federal beef cattle research programs were estimated using an economic surplus approach. The internal rate of return on research expenditure from 1968 to 1984 was found to be 63% at the margin, indicating substantial underinvestment in technological change. Evidence indicative of underinvestment was found even when an adjustment was made to research costs to reflect the marginal excess burden of taxation. Most of the benefits of beef cattle research conducted during this time period accrued to farmers.

## 1. INTRODUCTION AND BACKGROUND

Investments in agricultural research have for the most part generated high net social benefits. Carter et al. (1984) summarize the results of an international cross section of studies which show annual internal rates of return to agricultural research ranging from 16% to 110%.[1] Benefits from agricultural research are typically difficult for a single investor to capture without the aid of a patent or licencing arrangement. These instruments are often unavailable to agricultural researchers. As a result, extensive public sector support for agricultural research has emerged in many countries. In Canada in 1984, approximately 2353 professionals were employed in agricultural research. Of that total, 2090 were employed by federal or provincial governments or by universities. The remaining 263 were employed by private industry or other establishments (CARC, 1985).

A limited number of estimates of net social benefits of Canadian agricultural research are available.[2] None of the studies conducted to date have estimated rates of return for livestock research in Canada and only a small number of estimates of net benefits of livestock research are available from other countries.[3] This paper seeks to augment the limited set of estimates of net social benefits of Canadian agricultural research and to address the international lack of assessments of livestock research. Livestock commodities are an important source of farm revenue in Canada[4] and elsewhere. Federally funded expenditures on beef cattle research in Canada totalled $13.89 million in 1984.[5] Federal expenditures on beef cattle research represented 0.39% of farm cash receipts in 1984, up from 0.17% in 1968.

Figures 1 and 2 compare the share of Canadian federal livestock

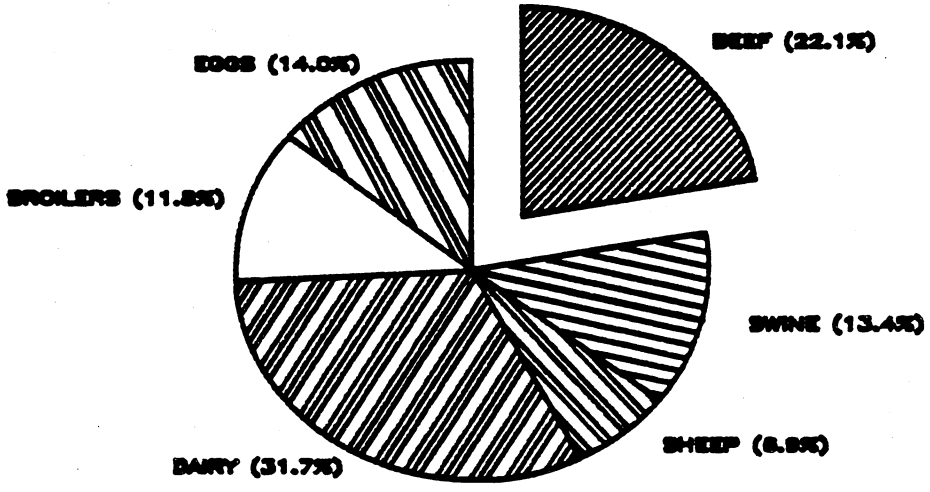
research expenditures devoted to beef research to the share of gross farm receipts derived from corresponding livestock commodities. In 1968, beef research expenditures were about 22% of total livestock research expenditures, while revenue from beef production amounted to over 40% of gross farm receipts from livestock. By 1984, the share of livestock research spending on beef had risen to almost 35%, and the share of gross revenues had fallen slightly to 37%, indicating a closer correspondence to the concept of congruence discussed by Boyce and Evenson (1975) and Ruttan (1983). Total federal and provincial expenditures on beef cattle research from 1955 to 1984 are reported in Figure 3. Federal expenditures remained fairly constant through the last half of the 1950's and through to the mid 1960's. Spending began to increase markedly in the late 1960's. Expenditures climbed to $16 million by 1979, but funding for beef research dropped sharply after 1979, falling to approximately $11 million in the early 1980's.

## 2. MEASUREMENT OF THE GROSS ANNUAL RESEARCH BENEFITS

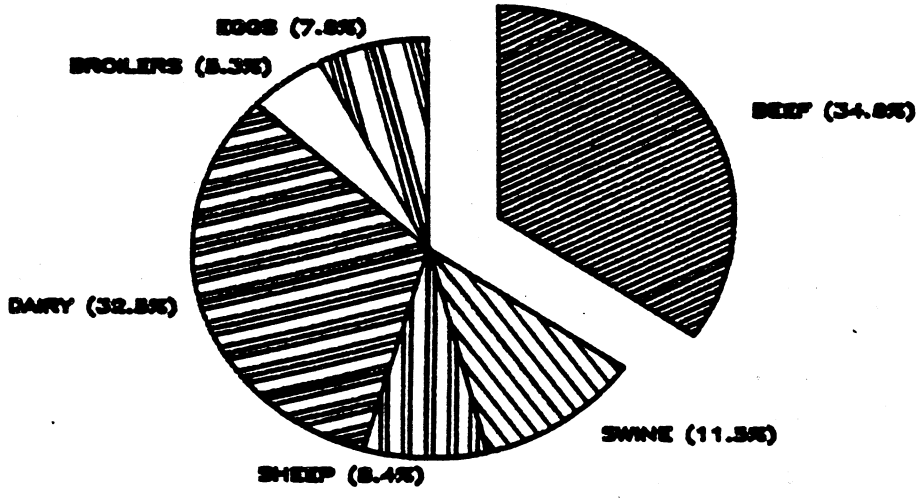
Norton and Davis (1981) identify six approaches developed by economists to evaluate returns to agricultural research. The economic surplus approach is well suited to the purposes of this study as it estimates the impact of agricultural research on the economic welfare of producers and consumers.[6] The economic surplus approach measures the gross benefits of research by comparing the position of the actual supply curve for a commodity with the supply curve that would have existed if the research in question had not been conducted. In Figure 4, the shift in the supply function attributable to research causes the market price for the commodity in question to fall from $P_1$ to $P_2$. The increase in the

Figure 1:

Distribution of federal expenditures on research on selected Livestock commodities, 1968, 1984.




1968

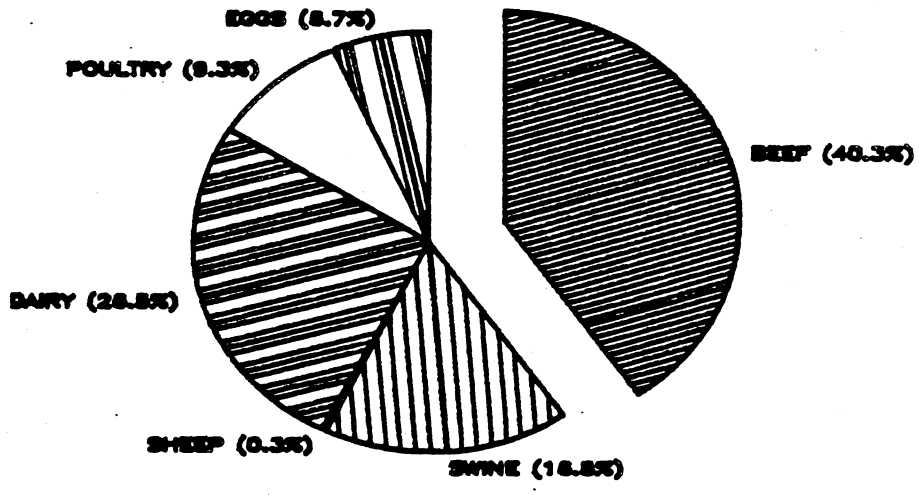



1984

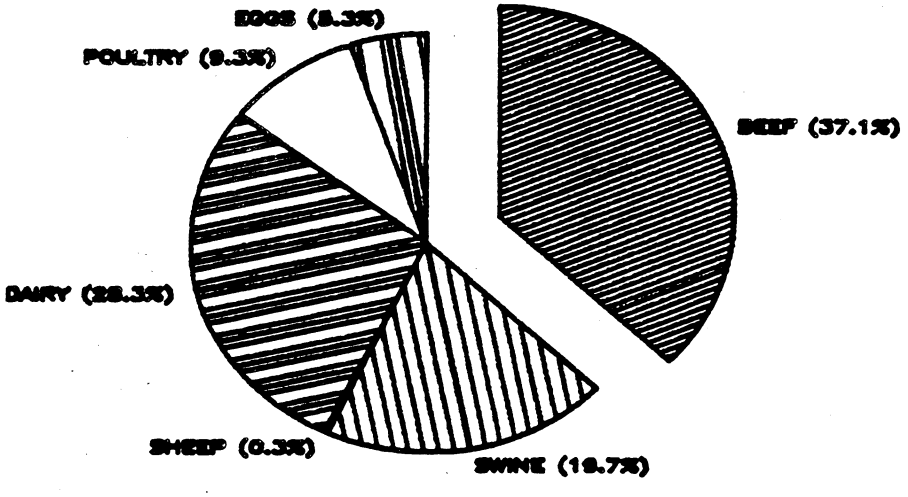
Source: Fox et al (1987)

Figure 2

Distribution of farm cash receipts by selected livestock commodity, 1968, 1984.



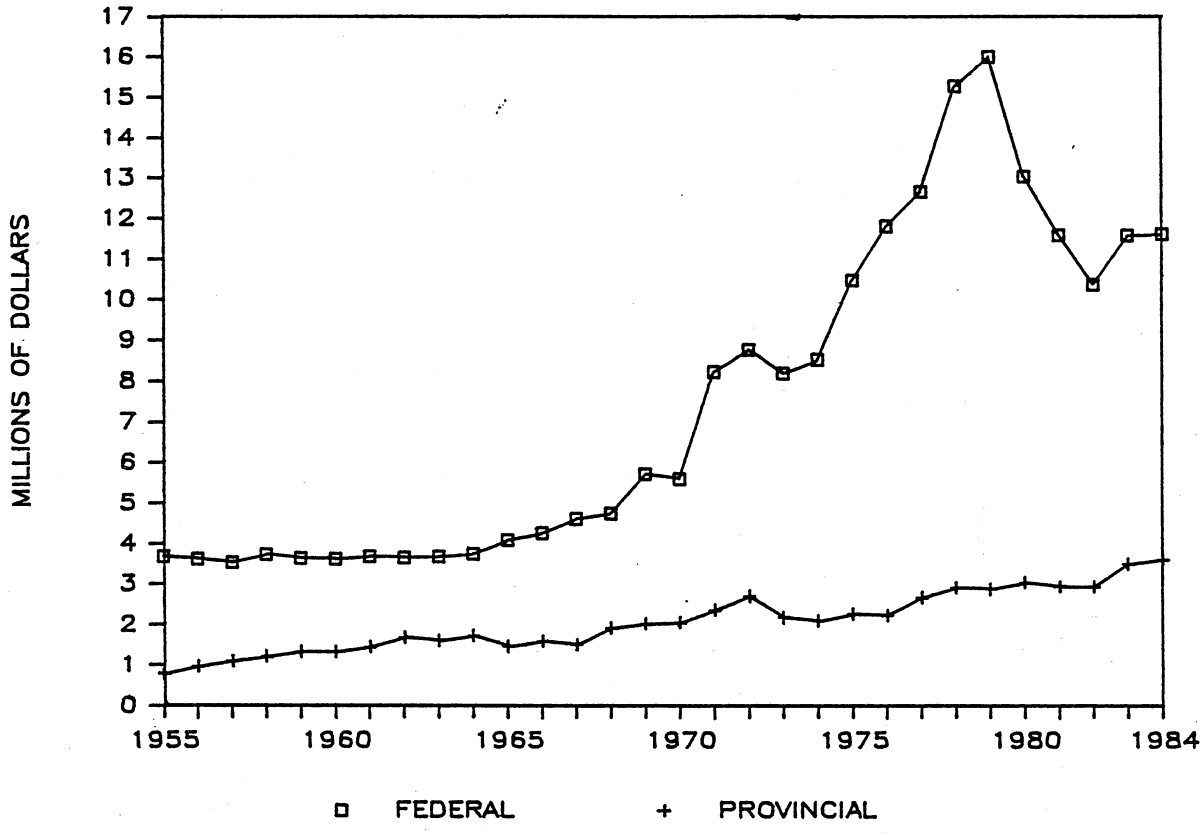

1968




1984

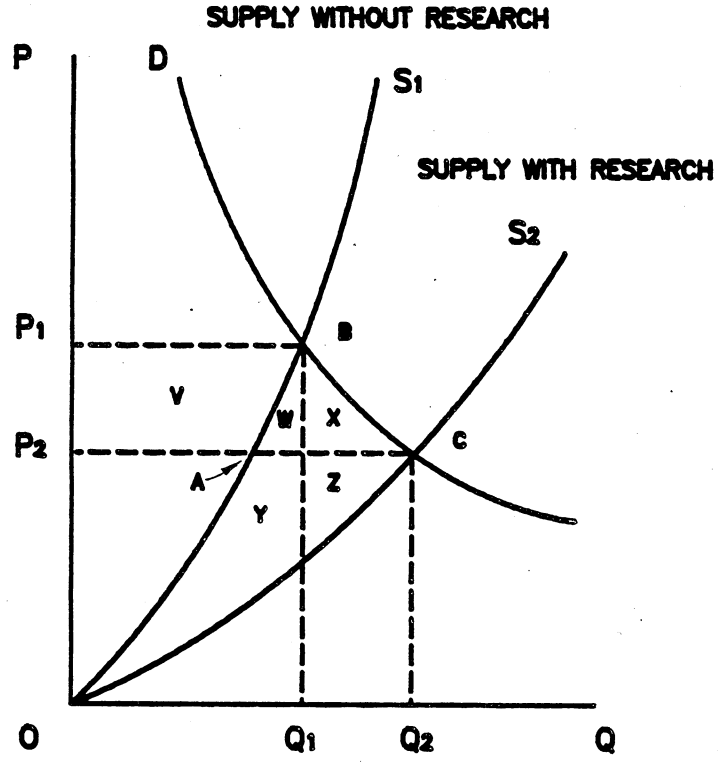
Source: Statistics Canada, Catalogue 21-202, Farm Net Income

Figure 3: Annual Federal and Aggregate Provincial Expenditures on Beef Research, 1955-1984 (Constant 1981 Dollars)




Source: Fox et al. (1987).

Figure 4: Social Surplus Model: Estimation of Gross Annual Research Benefits Using Shifts in Supply Curves




Source: Fox et al. (1987)

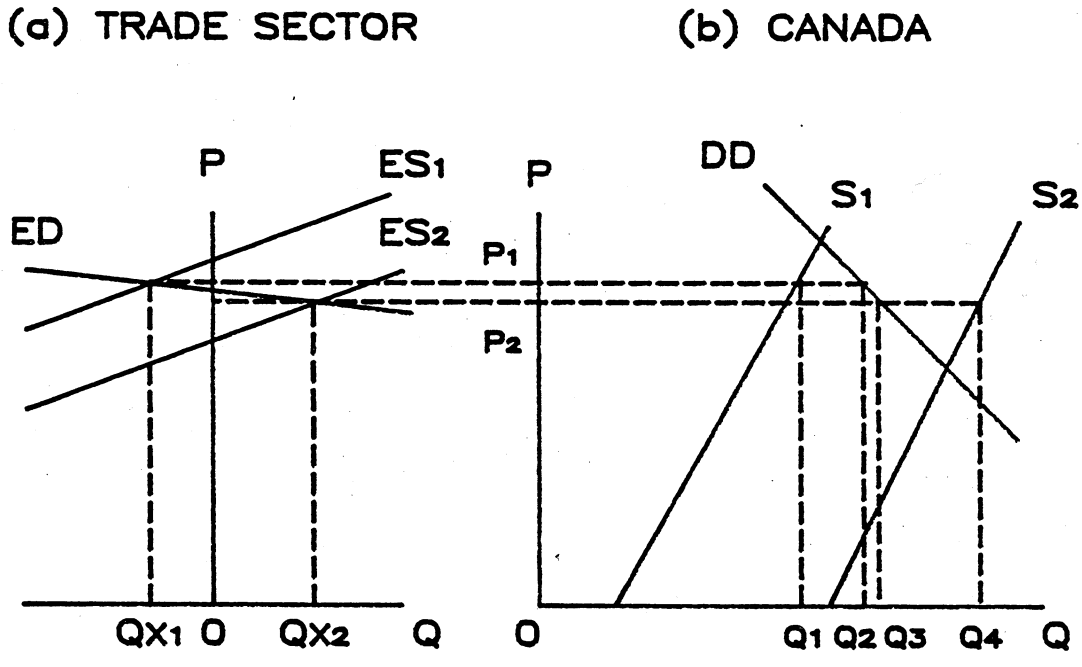
economic welfare of consumers, measured as the change in Marshallian consumers' surplus, is the area V + W + X. Producers lose the area V, which represents a reduction in producers' surplus, but they gain the area Y + Z. The net change in producers' and consumers' surpluses is W + X + Y + Z, which constitutes the gross benefit of research.

Lindner and Jarrett (1978) noted that the manner in which the supply curve shifts influences the size and the distribution of gross research benefits. Traditionally, applications of this approach have used a rate of productivity change over time to represent the rate of shift of the supply function and the type of shift has been assumed arbitrarily. Time series data collected for the present study enabled the direct estimation of the supply function. Inclusion of lagged research expenditures as explanatory variables made it possible to estimate the rate at which research has been shifting the aggregate supply function through time. Comparison of alternative functional forms for the supply function made it possible to identify the type of supply shift. A linear function, which produces a parallel shift and a partial-logarithmic function, which produces a divergent proportional shift were estimated.[7] Direct estimation of the supply function also permits the estimation of research benefits at the margin. By adding a small increment to the actual research expenditures a new hypothetical supply curve is generated. The area between this supply function and the actual supply function, below the demand function, constitutes the gross benefit of this incremental expenditure. Comparison of this gross benefit with the size of the perturbation of the actual research expenditures yields an estimate of net benefits at the margin. It is precisely this marginal rate of return that is of interest in questions of allocative efficiency in the public

sector. Earlier attempts to use the economic surplus approach to study returns to research have been criticized for not being able to produce estimates of net benefits at the margin.

Canadian beef is sold in an integrated north american market. As a consequence, the diagrammatic treatment of Figure 4 is inadequate if we wish to measure the benefits of Canadian beef research accruing to domestic consumers and producers. Figure 5 illustrates the effect of the interaction of the Canadian excess beef supply (ES) and the United States excess beef demand (ED) curves on the price of Canadian beef. The price for beef in Canada not including tariffs and transportation is essentially determined by the intersection of the excess supply and demand curves in the trade sector. Without Canadian beef research, the Canadian supply curve is $S_1$ and the excess supply curve is $ES_1$. At equilibrium price $P_1$, Canadian beef producers supply quantity $Q_1$. Beef consumers demand quantity $Q_2$. The result is an excess demand in the Canadian market. Assuming there are no additional imports from third countries, American producers will export $QX_1$ to Canada. Canadian beef research expenditures shift the Canadian supply curve to position $S_2$. Correspondingly, the excess supply curve is shifted to $ES_2$. This curve now intersects the excess demand curve at $P_2$. At this price, Canadian producers provide quantity $Q_4$, while Canadian consumers require only $Q_3$. The excess supply is equal to the United States' excess demand $QX_2$ and is exported to the American market. In this context, Canadian consumers' welfare increases by the area under the domestic demand function as price falls from $P_1$ to $P_2$. Canadian producers lose the area between $P_1$ and $P_2$ to the left of $S_1$ but gain the area between $S_1$ and $S_2$ below $P_2$. In the present analysis, gross annual research benefits are measured as

Figure 5: The Effect of Canadian Excess Supply and United States Excess Demand Curves on the Price of Canadian Beef



the net change in producers' surplus for Canadian suppliers plus the increase in consumers' surplus for Canadian consumers. Gains to U.S. consumers arising as a consequence of Canadian research as well as the welfare effects of Canadian research on beef producers in the United States are ignored.

## 3. ESTIMATION OF THE SUPPLY FUNCTION

Table 1 reports parameter estimates for the supply function. A single equation was estimated at the national level using annual time series data. Output in the estimated equation is an aggregate of all grades of beef production. National production of each grade of beef is converted to an equivalent quantity of A1/A2 steer carcass based on the price of that grade relative to the A1/A2 steer price.

The output price is an annual weighted average price per metric tonne of beef from A1/A2 steers sold through Calgary, Winnipeg and Toronto stockyards. These were the most important stockyards in terms of volume of beef cattle sales in the country throughout the period under consideration. Prices were lagged two years to reflect biological lags in the supply of beef. The price of feed is represented by the price per metric ton of corn on track in Chatham. This variable was lagged one year. The Cattle and Calf Inventory includes all bulls, beef steers, beef heifers and beef cows.[8] In addition, a percentage of the previous year's beef cows is used to approximate the annual beef calf crop. The inventory is in terms of thousands of head and is lagged two years.

The Index of Education and Provincial Research and Extension captures the influence of the ten provincial governments' contributions in research and extension on beef as well as the impact of higher levels of

Table 1: The Beef Supply Function

Dependent Variable: A1, A2 Steer Carcass Equivalent Supply in Canada

Functional Form: Linear

Sample: 1967-1984

| Explanatory Variable | Coefficient | t-Statistic | Elasticity |
|---|---|---|---|
| Constant | 153226.3 | 2.62 | |
| Output Price (t-2) | 79.2 | 6.16 | 0.39 |
| Price of Corn (t-1) | -932.1 | -8.23 | -0.21 |
| Cattle/Calf Inventory (t-2) | 41.6 | 6.00 | |
| Index of Education and Provincial Research | 698.7 | 0.90 | |
| Exotic Cattle Breeds (t-1) | 477.5 | 0.35 | |
| Pork Production (t-1) | -260.0 | -3.23 | |
| Canadian Federal Research | | | |
| t-4 | 0.69 | 3.76 | 0.01 |
| t-5 | 1.27 | 3.76 | 0.02 |
| t-6 | 1.74 | 3.76 | 0.03 |
| t-7 | 2.11 | 3.76 | 0.03 |
| t-8 | 2.38 | 3.76 | 0.04 |
| t-9 | 2.53 | 3.76 | 0.04 |
| t-10 | 2.58 | 3.76 | 0.04 |
| t-11 | 2.53 | 3.76 | 0.04 |
| t-12 | 2.38 | 3.76 | 0.04 |
| t-13 | 2.11 | 3.76 | 0.03 |
| t-14 | 1.74 | 3.76 | 0.03 |
| t-15 | 1.27 | 3.76 | 0.02 |
| t-16 | 0.69 | 3.76 | 0.01 |
| SUM | 24.02 | | 0.36 |

Table 1 continued

| Explanatory Variable | Coefficient | t-Statistic | Elasticity |
|---|---|---|---|
| U.S. Research | | | |
| t-4 | 0.004 | 0.05 | |
| t-5 | 0.008 | 0.05 | |
| t-6 | 0.010 | 0.05 | |
| t-7 | 0.011 | 0.05 | |
| t-8 | 0.012 | 0.05 | |
| t-9 | 0.011 | 0.05 | |
| t-10 | 0.010 | 0.05 | |
| t-11 | 0.008 | 0.05 | |
| t-12 | 0.004 | 0.05 | |
| SUM | 0.078 | | |
| | R-Squared: | 0.985763 | |
| | Adjusted R-Squared: | 0.973107 | |
| | Durbin-Watson: | 2.505306 | |
| | F-Statistic: | 77.89292 | |

education in the farm labour force. This index is constructed as the average of an index of farmers' education, an index of the sum of provincial government expenditures on beef research and an index of provincial government expenditures on beef production related extension programs. The education index was adopted from Hunt (1984) and extended using census data. Provincial expenditures were obtained from the public accounts of the ten provinces. Most provinces report research and extension budgets in aggregate but do not report the costs of programs by commodity. The share of total provincial agricultural research devoted to beef cattle was assumed to be the same as the share of personnel involved in beef research derived from CARC records. The share of provincial extension expenditures devoted to beef cattle programs was assumed to be the same as the share of gross farm receipts obtained from beef.

The percentage of exotic cattle in the national beef herd is included to reflect the spill-in effects of European genetic material. This percentage was estimated based on annual purebred registrations obtained from the breed associations. National pork production, measured as million metric tons of chilled dress carcass, was included in the equation to capture the competition for quasi-fixed factors on mixed livestock farms that produce both hogs and beef.

Canadian federal research expenditures were calculated from Agriculture Canada records. Expenditures for 1968-1984 were available disaggregated by commodity. Only total research expenditures were available for earlier years. Beef research prior to 1968 was assumed to receive the same share of total research funding as it did from 1968 to 1971. Detailed description of sources and procedures used in the

construction of a time for Canadian federal beef research expenditures is reported in Fox et al. (1987). Total U.S. federal research expenditure on beef cattle are included to reflect the potential spill-in of technology from research programs in the United States. Data were obtained from the Current Research Inventory System (CRIS) maintained by the USDA and from the House of Representatives Appropriations Hearings for the USDA (see Widmer, (1987) for details).

The sign of each of the estimated coefficients is consistent with economic theory. The low values of the t-statistics for the index of extension, provincial research and farmers' education level, for proportion of exotic breeds and for U.S. research indicates that these variables had a weak influence on the beef supply function in Canada during the period 1967 to 1984. The elasticity of the supply function with respect to output price lagged two years was estimated to be 0.39. This is a short-run elasticity as the effect of price changes on the beef inventory variable are not included. Liu and Roningen (1985) reported an estimate of the elasticity to be 0.12. Haack et al. (1978) found that the elasticity for eastern Canada was 0.357 compared to 0.044 for western Canada. The estimate obtained in this study for a national model with annual data seems reasonable in light of other research.

Canadian federal beef research was found to shift the national supply function for a period between 4 and 16 years after the research expenditures had been made.[9] This is a relatively long lag structure, indicating that while some technological change generated by research is incorporated into management practices at the industry level relatively quickly, the full impact of research is not seen for some time. This long lag structure can be attributed to the relatively low turnover rate

of breeding stock in beef production relative to the poultry and swine industries. The long-run effect of a 1% increase in research funding would be a 0.36% shift in the supply function.

## 4. NET BENEFIT CALCULATIONS

The supply function reported in Table 1 is used to calculate the gross benefits of Canadian beef cattle research conducted between 1968 and 1984 using the procedures described earlier. Given the estimated lag structure, gross benefits are computed for each year from 1972 to 2001. Values of variables beyond 1984 are projected at their 1984 values. Gross benefits are compared with treasury costs less recoverable revenues to obtain measures of net benefits. Sales of livestock products generated in association with the maintenance of beef herds on experiment stations offset more than 10% of the treasury costs of research on beef cattle. Since these revenues accrue directly to the federal treasury and do not affect the management of the research facilities, the gross treasury costs of research were used to represent the size of the research effort in the estimation of the supply function. In the calculation of net benefits, however, recoverable revenues are deducted from the gross treasury costs to obtain the net social cost of beef cattle research.

Total annual benefits of beef research and the distribution of the benefits among consumers and producers are reported in Table 2. At a 5% real discount rate, economic benefits over 29 years total over $5 billion. On average, nearly 90% of benefits accrue to beef producers. The remaining 10.4% of benefits or $522 million are distributed among Canadian beef consumers.

Table 2: Distribution of Realized Research Benefits for Beef
(Millions of Constant 1981 Dollars)

| Year | Real Discount Rate | Gross Annual Research Benefits | | Change in Producers' Surplus | | Change in Consumers' Surplus | |
|---|---|---|---|---|---|---|---|
| | | $ | % | $ | % | $ | % |
| 1972 | | 10.4 | 100.0 | 9.5 | 90.6 | 1.0 | 9.4 |
| 1973 | | 33.1 | 100.0 | 30.1 | 90.7 | 3.1 | 9.3 |
| 1974 | | 66.9 | 100.0 | 61.2 | 91.5 | 5.7 | 8.5 |
| 1975 | | 131.5 | 100.0 | 120.5 | 91.7 | 11.0 | 8.3 |
| 1976 | | 183.4 | 100.0 | 165.1 | 90.0 | 18.3 | 10.0 |
| 1977 | | 214.7 | 100.0 | 187.5 | 87.3 | 27.2 | 12.7 |
| 1978 | | 229.3 | 100.0 | 196.5 | 85.7 | 32.8 | 14.3 |
| 1979 | | 280.8 | 100.0 | 244.2 | 87.0 | 36.6 | 13.0 |
| 1980 | | 454.7 | 100.0 | 411.0 | 90.4 | 43.6 | 9.6 |
| 1981 | | 635.5 | 100.0 | 584.3 | 92.0 | 51.1 | 8.0 |
| 1982 | | 673.4 | 100.0 | 612.0 | 90.9 | 61.4 | 9.1 |
| 1983 | | 689.0 | 100.0 | 618.1 | 89.7 | 70.9 | 10.3 |
| 1984 | | 708.2 | 100.0 | 634.9 | 89.7 | 73.3 | 10.3 |
| 1985 | | 764.4 | 100.0 | 685.6 | 89.7 | 78.8 | 10.3 |
| 1986 | | 808.6 | 100.0 | 725.5 | 89.7 | 83.1 | 10.3 |
| 1987 | | 843.7 | 100.0 | 757.3 | 89.8 | 86.4 | 10.2 |
| 1988 | | 867.5 | 100.0 | 778.7 | 89.8 | 88.7 | 10.2 |
| 1989 | | 859.4 | 100.0 | 771.4 | 89.8 | 87.9 | 10.2 |
| 1990 | | 823.6 | 100.0 | 739.1 | 89.7 | 84.5 | 10.3 |
| 1991 | | 761.7 | 100.0 | 683.2 | 89.7 | 78.5 | 10.3 |
| 1992 | | 677.9 | 100.0 | 607.6 | 89.6 | 70.3 | 10.4 |
| 1993 | | 580.0 | 100.0 | 519.4 | 89.6 | 60.6 | 10.4 |
| 1994 | | 475.1 | 100.0 | 425.0 | 89.5 | 50.0 | 10.5 |
| 1995 | | 369.0 | 100.0 | 329.8 | 89.4 | 39.2 | 10.6 |
| 1996 | | 272.0 | 100.0 | 242.9 | 89.3 | 29.1 | 10.7 |
| 1997 | | 190.0 | 100.0 | 169.5 | 89.2 | 20.5 | 10.8 |
| 1998 | | 120.9 | 100.0 | 107.8 | 89.2 | 13.1 | 10.8 |
| 1999 | | 65.0 | 100.0 | 57.9 | 89.1 | 7.1 | 10.9 |
| 2000 | | 22.8 | 100.0 | 20.3 | 89.1 | 2.5 | 10.9 |
| 2001 | | 0.0 | | 0.0 | | 0.0 | |
| Average | | | 100.0 | | 89.6 | | 10.4 |
| Present Value of Gross Benefits | | | | | | | |
| Real | 2% | 8687.8 | 100.0 | 7784.3 | 89.6 | 903.5 | 10.4 |
| Discount | 5% | 5025.1 | 100.0 | 4502.5 | 89.6 | 522.6 | 10.4 |
| Rate | 10% | 2200.2 | 100.0 | 1971.4 | 89.6 | 228.8 | 10.4 |

Table 3: Net Benefits of Federal Beef Research Expenditures

| | Internal Rate of Return | Real Discount Rate 2% | 5% | 10% |
|---|---|---|---|---|
| Average Benefits | 65.8% | | | |
| Net Present Value (Million 1981 $) | | 8555.0 | 4821.2 | 2127.6 |
| Benefit/Cost Ratio | | 65.4 | 48.3 | 30.3 |
| Marginal Benefits | 63.0% | | | |
| Net Present Value (Million 1981 $) | | 82.5 | 47.5 | 20.5 |
| Benefit/Cost Ratio | | 57.5 | 42.5 | 26.7 |

Net benefit calculations are shown in Table 3. The average internal rate of return is nearly 66% and the marginal rate of return is 63%. This suggests that the level of funding for beef research in Canada has been too low.

The net present value of beef research conducted between 1968 and 1984 is over $4.9 billion when evaluated with a 5% real discount rate. The benefit/cost ratio is 48.3:1 when discounted at 5%. At the margin, the benefit/cost ratio is 42.5:1.

Figure 4 shows how the marginal excess burden of taxes tends to decrease the benefits to beef research. The internal rate of return falls to 61.5% on an average basis, while at the margin, the return is reduced to approximately 59%. At a 5% discount rate, the net present value of the benefits are down only slightly. The benefit/cost ratio is reduced substantially to 39.3:1. Similar effects occur at the margin, with the net present value of beef research falling only slightly, while the benefit/cost ratio is reduced to 35.4:1. Despite these reductions, all benefit measures remain relatively high.

## 5. DISCUSSION

The results of this study indicate that federal expenditures on beef cattle research in recent years have generated substantial net benefits to the Canadian economy. The majority of these benefits have occurred as increased economic welfare of farmers. Furthermore, the extension of the economic surplus approach developed in this paper suggests that net benefits of recent research have not only been high on average, but that rates of return at the margin are indicative of underinvestment in public beef cattle research. This conclusion is not changed by the

Table 4: Net Benefits of Federal Beef Research Expenditures Adjusted for the Marginal Excess Burden of Taxes

| | Internal Rate of Return | Real Discount Rate 2% | 5% | 10% |
|---|---|---|---|---|
| Average Benefits | 61.5% | | | |
| Net Present Value (Million 1981 $) | | 8524.3 | 4897.3 | 2111.0 |
| Benefit/Cost Ratio | | 53.6 | 39.3 | 24.7 |
| Marginal Benefits | 59.0% | | | |
| Net Present Value (Million 1981 $) | | 82.2 | 47.2 | 20.4 |
| Benefit/Cost Ratio | | 47.9 | 35.4 | 22.2 |

inclusion of the marginal excess burden of taxation in the cost of public research.

Previous studies have frequently ignored the role of recoverable revenues in the evaluation of net benefits of research. In the case of beef cattle research in Canada, recoverable revenues offset a considerable portion of the treasury cost of research and have an important influence on the calculation of net social benefits.

## FOOTNOTES

1 See also Ruttan (1982), Chapter 10.

2 See Nagy and Furtan (1978), Zentner and Peterson (1984), Brinkman and Prentice (1984), Zentner and Peterson (1984) and Ulrich, Furtan and Schmitz (1986).

3 See Bredahl and Peterson (1976) who studied returns to livestock research in the United States.

4 Farm cash receipts for all forms of livestock accounted for approximately half of the $20.3 billion (current dollars) in gross revenues received by Canadian producers in 1984. Receipts for beef and veal alone totalled $3.6 billion. In 1968, beef and veal accounted for $980 million of the $4.36 billion total farm cash receipts.

5 See Fox et al. (1987).

6 The economic surplus model was pioneered by Griliches (1958) and has also been used by Akimo and Hayami (1978) and by Zentner (1983).

7 Lindner and Jarrett argued that these two types of shift were the most reasonable candidates on empirical and theoretical grounds.

8 Alternative specifications of the cattle and calf inventory variable which included estimates of dairy cow numbers were also explored. Regression results with these specifications were plagued by serial correlation in the residuals so the present version of the model was retained. Beef output from the dairy herd is generally considered to be driven by economic conditions in the dairy industry with only secondary influence attributed to conditions in the beef market. This explanation could account for the poor performance of inventory variables which included the dairy herd.

9 The zero end point constraints on the Canadian federal research lag were tested statistically and were not rejected by the data.

## REFERENCES


Agriculture Canada (1980). FARM, Food and Agriculture Regional Model (II) Livestock, Policy Planning and Economics Branch (Draft).

Akino, M. and Y. Hayami (1975). "Efficiency and Equity in Public Research: Rice Breeding in Japan's Economic Development", American Journal of Agricultural Economics, Vol. 57, pp. 1-10.

Boyce, James K. and Robert E. Evenson (1975). Agricultural Research and Extension Programs, Agricultural Development Council, New York.

Brinkman, George and Barry Prentice (1983). Multifactor Productivity in Canadian Agriculture: An Analysis of Methodology and Performance 1961-1980, School of Agricultural Economics and Extension Education, University of Guelph, May.

Canadian Agricultural Research Council (1985). ICAR: Inventory of Canadian Agri-food Research, 1984, Report for the Canadian Agricultural Services Coordinating Committee, pp. 1.

Carter, C., Barry Prentice and A. Schmitz (1984). The Economics of Agricultural Research: A Discussion Paper Prepared by the Agricultural Institute of Canada, Supplement to Agronews, Sept. 1984.

Fox, Glenn (1985). "Is the United States Really Underinvesting in Agricultural Research?", American Journal of Agricultural Economics, Vol. 67, #4, Nov. pp. 806-812.

Fox, Glenn, George Brinkman and Nancy Brown-Andison (1987). An Economic Analysis of the Returns to the Animal Productivity Research Program of Agriculture Canada from 1968 to 1984. Prepared by Intercambio Ltd. under contract for Agriculture Canada.

Griliches, Z. (1958). "Research Costs and Social Returns: Hybrid Corn and Related Innovations", Journal of Political Economy, Vol. 66, pp. 419-431.

Haack, R. E. (1978). An Analysis of the Economic Implications of Supply Management and Stabilization Programs in the Canadian Beef Sector, M.Sc. Thesis, University of Guelph.

Lindner, R. K. and F. G. Jarrett (1978). "Supply Shifts and the Size of Research Benefits", American Journal of Agricultural Economics, Vol. 62, #4, Nov. pp. 48-58.

Meilke, Karl D. and Jonathan R. Coleman (1986). An Evaluation of the Influence of Exchange Rates on the Canadian Red Meat Sector, Dept. of Agricultural Economics and Business, Ontario Agricultural College, University of Guelph, AEB/86/4.

Nagy, J. G. and W. H. Furtan (1978). "Economic Costs and Returns from Crop Development Research: The Case of Rapeseed Breeding in Canada", Canadian Journal of Agricultural Economics, Vol. 26, pp. 1-14.

Norton, George W. and Jeffrey S. Davis (1981). "Evaluating Returns to Agricultural Research: A Review", American Journal of Agricultural Economics, Vol. 63, #4, Nov. pp. 685-699.

Ruttan, Vernon W. (1982). Agricultural Research Policy, Minneapolis, University of Minnesota Press.

Schultz, T. W. (1953). The Economic Organization of Agriculture, New York: McGraw-Hill Book Co.

Statistics Canada, Various Years, Farm Cash Receipts, Catalogue 21-001.

Stigler, George J. (1966). The Theory of Price, 3rd Edition, London: The MacMillan Co., pp. 89-91, 342.

Zentner, R. P. (1983). "Returns to Public Investment in Canadian Wheat and Rapeseed Research", in Economics of Agricultural Research in Canada, Ed. K.K. Klein and W.H. Furtan, Calgary: The University of Calgary Press, 1985, pp. 169-188.