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Canadian dairy policy and the returns to federal dairy cattle research

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ABSTRACT

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The economic surplus approach is used to estimate the returns to federal investments in dairy cattle research in Canada. A national supply function is estimated using time series data. Lagged research expenditures are included as explanatory variables in the model, facilitating the calculation of marginal as well as average benefits from research. Simulation analysis is used to study the effects of product market distortions associated with Canadian dairy policy as well as of the marginal excess burden on the rates of return to research and on the distribution of research benefits. Returns were found to be high at the margin. Distortions in the product market had a small effect on the overall returns to dairy cattle research but had a large impact on the distribution of research benefits. Rate of return estimates were found to be indicative of underinvestment even when the marginal excess burden was taken into account.

INTRODUCTION

Oehmke (1988) has recently argued that intervention in the product market for an agricultural commodity can have a significant impact on the rate of return to investments in agricultural research. Failure to properly characterize the nature of intervention can bias estimates of the net benefits of research. Oehmke's contribution reinforces earlier work by Fox

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(1985), Alston et al. (1988) and De Gorter and Norton (1988) that has shown that agricultural policy matters in the estimation of returns to agricultural research. With only a few exceptions [1], little progress has been made in the measurement of how much policy matters for specific commodities. The purpose of this paper is to investigate the extent to which supply controls and formula pricing in the Canadian dairy industry have influenced both the size and the distribution of benefits from public investments in dairy cattle research.

BACKGROUND

Publicly funded agricultural research in Canada began with the Department of Agriculture Act of 1886 and the Experimental Farm Stations Act of the same year. These were followed by the Act Respecting Contagious Diseases of Animals in 1879 and the Canada Grains Act of 1930. Agriculture Canada research is undertaken by the Research Branch, the Animal Pathology Division of the Health of Animals Directorate of the Food Production and Inspection Branch, and the Grain Research Laboratory of the Canadian, Grain Commission. At the federal level the National Research Council of Canada also does a significant amount of agricultural research (Guitard, 1985, p. 24).

Federal expenditures support dairy research at seven Research Stations, as well as at Canadian Universities. In 1984, Agriculture Canada spent $10.9 million (in constant 1981 Canadian dollars) on dairy research. Over the period 1955 to 1984, the federal government spent an average of $8.0 million per year (in constant 1981 Canadian dollars) on dairy research, which amounted to about 31% of total livestock research expenditures. Provincial expenditures on dairy research in 1984 were $3.7 million (in constant 1981 Canadian dollars).

The dairy industry in Canada has undergone a number of major technological and structural changes since the early 1960's. Dairy farm numbers have fallen sharply and average herd size has increased. A 32% decrease in the total number of farms in Canada occurred between 1966 and 1986 while the number of farms that were classified as containing a dairy enterprise for census purposes declined by 80%. The proportion of Holstein–Friesian cows increased from 70% to 85%, while breeds such as the Brown Swiss and the Canadienne have virtually disappeared. Dairy farms are now generally specialized in milk production. Production systems are more mechanized and designed to handle larger quantities of milk with

[1] See Zachariah et al. (1989) and Haque et al. (1989).

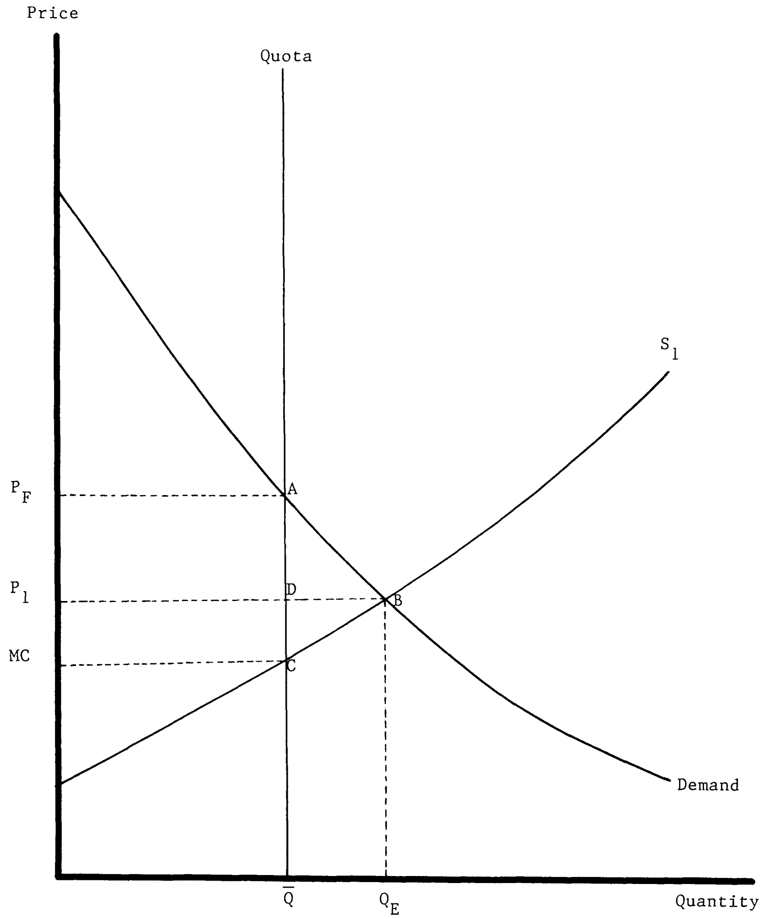

Fig. 1. Income transfer and welfare loss associated with Canadian dairy policy price.

pipeline and milk parlour systems. Breeding is mainly through artificial insemination, and the use of embryo transplants from higher-quality cows to poorer-quality nurse cows, allows faster upgrading of dairy herd quality.

CANADIAN DAIRY POLICY AND THE MEASUREMENT OF RETURNS TO RESEARCH

Milk production in Canada is regulated by a supply management system [2] based on production quotas for both manufacturing and fluid milk. The effect of dairy policy at the industry level is portrayed in Fig. 1. In the

[2] See Forbes et al. (1982), Stonehouse (1987), Barichello (1981) and Lavigne and Biggs (1985) for a description and review of Canadian dairy policy.

absence of trade in milk and other dairy products, the domestic price (P_1) would be determined by the interaction of domestic supply and demand. Market equilibrium production is represented as Q_E. At the formula price, P_F, only $\overline{Q}$ can be sold to domestic consumers, so the national quota is set at this level to support P_F. The area P_FADP_1 represents the income transfer from consumers to producers induced by this policy. Area $(P_F - MC)\overline{Q}$ is the rent accruing to quota holders, which becomes capitalized into the price of quota. Area ABC is the deadweight loss generated by the policy. Barichello (1981) estimated the annual income transfer from consumers to producers to be $680 million in 1980, and the deadweight loss to be $208 million.

The economic surplus approach to the estimation of research benefits views research expenditures as the source of technological change that shifts the supply function down and to the right. Gross benefits of research are estimated by comparing the actual supply function to the supply function that would have existed had research not been undertaken. In the absence of distortions in the product market, price falls and the quantity produced and consumed increases as research shifts the supply function to the right. As the market-clearing price falls, consumers' surplus increases. The net change in producers' surplus can be positive, zero or negative, depending on the elasticity of the demand function and the type of supply shift.

When the pricing function of the market is abrogated through public policy, the effects of changing technology on consumers and producers can change. The imposition of a quota in the product market also reduces the gross benefits from research. In Fig. 2, gross research benefits are the area C_0BDC_1, rather than $C_0E_0E_1C_1$. S_1 is the actual industry level supply function in a particular year. S_0 is the hypothetical supply function that would have existed in that same year if research had not been conducted during the period under study. Since the formula price P_F is not determined by the interaction of supply and demand, supply shifts of the type illustrated in Fig. 2 do not confer any benefits on consumers. If the shift in the supply function is sufficiently large, however, and/or if the quota is sufficiently close to the competitive market output level, then the supply function that would have existed had research not taken place, (S_0), can intersect domestic demand at a price higher than P_F. This situation is illustrated in Fig. 3. In this situation, research can yield benefits for consumers even under supply management. As research shifts the supply function, consumers can gain from the decline in price from P_0 to P_F. As a result, consumers' surplus increases by the area $P_0E_0E_FP_F$. The effect of research on producers' surplus is ambiguous. Without research, producers' surplus would have been $P_0E_0C_0$. Under S_1, with a quota imposed at $\overline{Q}$,

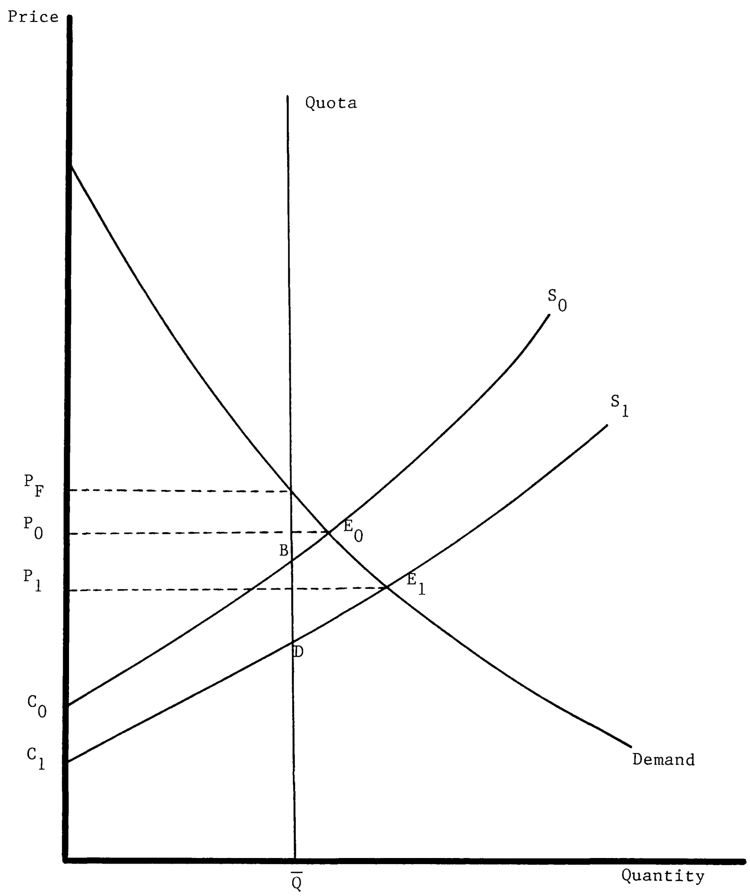

Fig. 2. Gross gains from research with an output quota – Case 1.

producers' surplus is $P_FE_FDC_1$. Depending on the elasticity of the domestic demand function and the type and size of the supply shift, $P_FE_FDC_1 - P_0E_0C_0$ can be positive, zero or negative. This last possibility turns out to be more than an abstract curiosity. The impact of research on producers' welfare was found to be negative in several years considered in this study, owing to the inelastic nature of the domestic demand function. Intervention in the market for milk reduces the net benefits of research relative to what benefits would have been in the absence of intervention. This reduction in benefits arises not because research has failed to generate new technology, but rather because distortions in the product market prevented the full exploitation of technological advance.

Returns to research at the margin are estimated by comparing the position of the actual supply function (see Fig. 4) in a particular year, S1, with the supply function that would have existed if research funding had

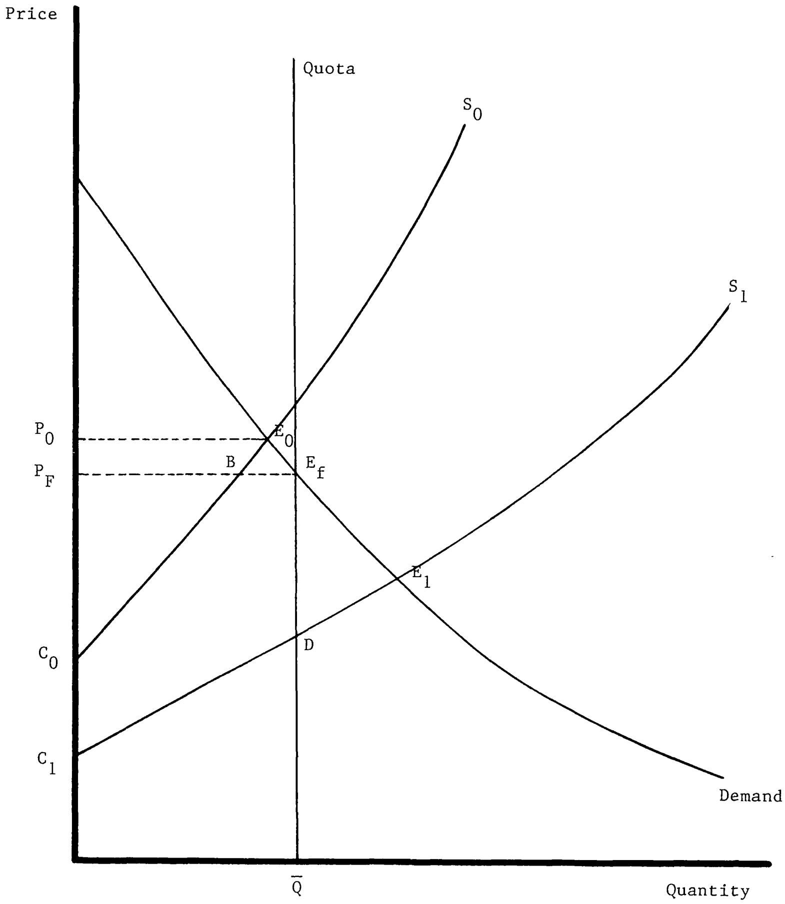

Fig. 3. Gross gains from research with an output quota – Case 2.

been increased by 1% in each year from 1968 to 1984, S_2. The area between these two supply functions up to the level of output determined by the quota is the gross benefit of this increased research. This gross benefit is compared with the dollar value of the 1% increase in funding to calculate net benefits. Figure 4 illustrates the procedure for the case of a binding quota. Calculations for other market conditions are performed analogously.

ESTIMATION OF THE SUPPLY FUNCTION

Traditionally, empirical studies of returns to agricultural research have estimated the rate at which the supply function shifts using changes in a single-factor or a multi-factor productivity index. The manner in which the

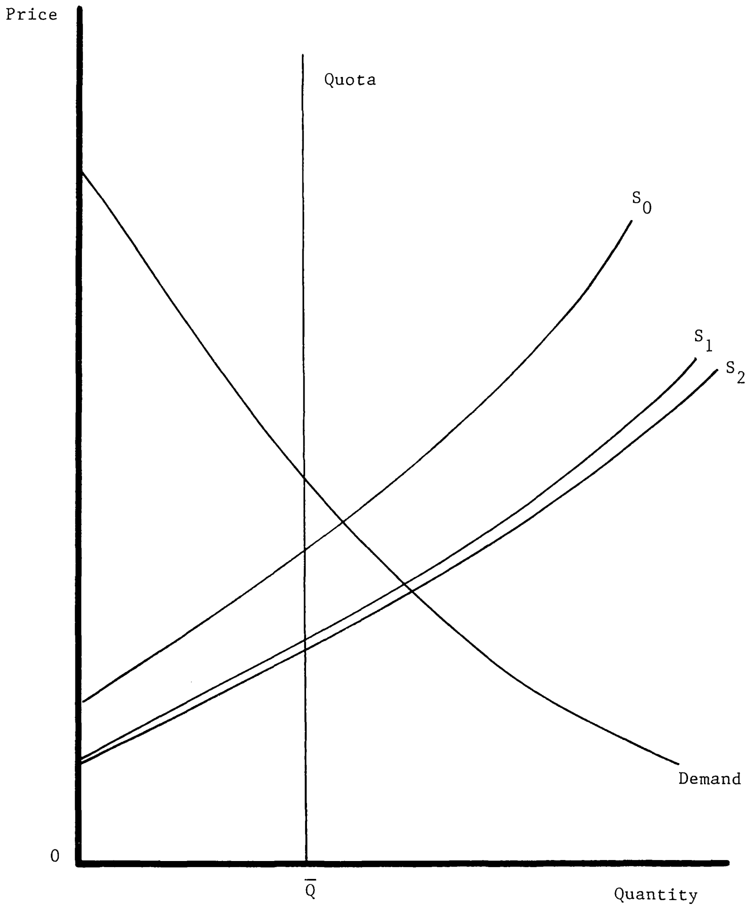

Fig. 4. Marginal research benefits.

supply function shifts along its length has been determined by assumption. A major difficulty with using a productivity index to estimate the rate of supply shift is that it does not provide an explicit link between the level of research expenditure and the size of the shift. As a result, its use restricts the analysis to evaluating only average benefits, whereas measurement of net benefits at the margin is needed to evaluate the efficiency of the allocation of research resources. In this study, following Haque et al. (1989), Zachariah et al. (1989) and Fox et al. (1990) the supply function is estimated directly rather than using productivity indexes, to facilitate the estimation of returns at the margin. Lagged values of relevant research expenditures are included as explanatory variables. Lindner and Jarrett (1978), Rose (1980), Wise and Fell (1980) and Lindner and Pannell (1990) have shown that estimates of net benefits are sensitive to the types of supply shift assumed, varying greatly between convergent, divergent and parallel shifts. This is a major limitation of many past studies using the economic surplus approach. Linear and partial-logarithmic forms of the supply functions were considered in this study. A linear functional form, for example:

$$Y = a + bP + cT \quad (1)$$

where Y represents output, P represents product price and T represents a technology shifter, generates a parallel shift in the supply function in price-output space. The effect of changes in T is incorporated into the intercept, and the supply function shifts by the same absolute vertical amount along its entire length. A partial-logarithmic function written as:

$$Y = \alpha P^{\beta} \exp(\gamma T) \quad (2)$$

generates a divergent proportional shift in the supply function in price-output space. The absolute magnitude of the vertical shift is smaller at lower levels of output. These two types of shift were identified by Lindner and Jarrett as being the most empirically relevant.

A number of factors could be thought to act as supply shifters over time. This paper focuses on the role of federal production-oriented dairy cattle research, including breeding and nutrition and feeding research performed under the Animal Productivity Research program of Agriculture Canada, as well as relevant disease research performed by the Animal Pathology Division. This research would be expected to shift farm-level cost functions down and to the right over time. This would be reflected in a rightward migration of the industry supply function in response to research. Research and extension performed by provincial ministries of agriculture, research spill-ins from the United States of America and farmers' education levels may also act as supply shifters. Inclusion of this extensive set of potential supply shifters was intended to prevent the attribution of effects of other variables to federal dairy research, which would have introduced an upward bias in the rate of return estimates.

Explanatory variables [3] used in the estimation of the national supply function included the expected price of milk, the inventory of dairy cows, the price of beef, an index of farm sector education level, provincial expenditures on dairy extension, provincial expenditures on dairy research, federal government expenditures on dairy research, U.S. expenditures on dairy research, and a dummy variable to represent period of supply-management.

[3] Data used in the estimation of the function are reported in Roberts (1988), and are available from the authors on request.

Milk output includes farm sales of fluid and industrial milk, milk equivalents of cream sold, and milk equivalents of estimated dairy livestock sales. Milk equivalent of dairy livestock sales were estimated by calculating livestock sales as a percentage of average dairy farm cash receipts from the Ontario Dairy Farm Accounting Project, the Ontario Farm Management Project and unpublished data from the British Columbia Ministry of Agriculture and Food. Dairy livestock sales average approximately 15% of total dairy farm cash receipts based on the available data. Total value of dairy livestock sold by dairy farms was estimated by calculating 15% of total Canadian Dairy Farm Cash Receipts, dividing this by the respective price of milk and adding the result to the volume of sales.

In a competitive market, the market equilibrium price is also the supply price. Under supply management, the price received by farmers is determined by the pricing formula and is higher than the price that would occur in a competitive market at the resulting level of production, the supply price. The difference between the price received by farmers and the supply price is the rental value per litre of quota. To determine the rent on quota, quota values for fluid and industrial milk were estimated for 1968 to 1984, the period within which the majority of milk production was governed by some form of control based on production quotas. Cream production was included in the calculations for industrial milk.

Time series data on provincial fluid and industrial quota prices are incomplete. Prices for Ontario and British Columbia are available for the entire time period, but are only reported for selected years for other provinces. A national weighted average quota price was calculated using the B.C. and Ontario data, where the weights on the Ontario prices were adjusted to reflect the relationship between Ontario quota prices and quota prices in other provinces for the years that observations were available. Detailed calculations are reported in Roberts (1988, Appendix C) and are available from the authors on request.

Based on Barichello (1984), quota values were discounted at 8% and amortized over four years to determine the quota rent. Barichello assumed that salvage value is zero for producer decision-making purposes (Barichello, 1984, pp. 19–29). If the assumption of a zero salvage value is incorrect, the quota rent estimated in this study will be higher than the true value. In the absence of specific information other than the Barichello study, we will use the zero salvage value assumption.

A weighted average rent, weighted by the proportion of fluid and industrial production per year, was calculated and deducted from a weighted average market price to estimate the supply price for each year between 1968 and 1984. The estimated supply price dropped rapidly starting in 1982 as the rent on quota increased due to sudden large jumps in quota prices across Canada. It was assumed that factors other than the rental value of quota were having an impact on the quota prices for the last 2 years in the sample. The supply price of milk for 1983 and 19S4, therefore, was estimated by using the 1979 to 1981 average rent as a percentage of market price to compute a supply price. Prices were lagged because of the delay in production response due to biological limitations on the speed with which producers can respond to changes in economic incentives.

Beef production may be regarded as being in competition with milk for the resources used in dairy production. A change in relative prices in favour of beef would be expected to draw resources toward meat production and away from milk production by affecting the producers decisions on culling cows and the use of pasture and other resources for beef instead of dairy. The price of slaughter cows was used as a competitive commodity price as a higher price for beef relative to milk could stimulate the transfer of resources away from the dairy enterprise and toward a beef enterprise.

Stonehouse, Harrington and Sahi (1978) and Scott and Smith (1986) included the price of 16% protein dairy feed in their models. A feed price variable was included in early versions of our model, but was deleted from the final version based on the statistical insignificance of the estimated coefficient. An index of farmers education (Hunt, 1984) was also included in earlier verisons of the model but subsequently dropped.

Stonehouse et al. (1978) and Scott and Smith (1986) also included the national inventory of dairy cows in their models. Some of the advances in breeding in the Canadian dairy industry have been made by private breeding organizations, often farmers' co-operatives. To ensure that the benefits from this private research were not attributed to public research expenditures, the number of cows in the national dairy herd were adjusted for the estimated contribution to milk production increases attributable to breeding improvements arising from private-sector investments in dairy cattle breeding research over the period under consideration. 1981 was used as the base year, so that the dairy herd size in each year is expressed as the number of 1981 genetic equivalent dairy cows. The adjustment was made by weighting the actual cow inventory by the percentage change in yield per cow which is attributable to private investments genetic improvement, estimated to be from 0.5% to 0.75% annual increase in yield per cow (Agric. Canada, 1983).

The adoption of technological changes may be influenced by changes in the level of education of dairy producers. Data on the level of education of dairy farmers were unavailable, therefore an index of years of formal education received by farmers in Canada was used as a proxy. Total Provincial extension expenditures were collected from the Provincial Public Accounts. Provincial expenditures on dairy research were calculated by allocating total provincial research expenditures to dairy based on the ratio of man-years of dairy research to total man-years of research in each province as reported by the Canadian Agricultural Research Council.

U.S. federal and state dairy research expenditures combined was used as a proxy for dairy research performed outside Canada, which may influence the technology used by producers in Canada. Federal expenditures on dairy research include operating costs, employee benefits, capital and grants, and a prorated share of administration, support, public works expenditures on livestock research facilities in the national capital region, and disease research carried out by the Animal Pathology Division. Finally, a dummy variable was included to capture any structural impact of the supply management system on the national supply function after 1968.

The estimated supply function is reported in Table 1. The estimated cumulative own price elasticity is 0.370, which is within the range of short run elasticities reported for Canada and the United States. Chen, Courtney and Schmitz (1972) reported a short-run elasticity of 0.381 and a long-run elasticity of 2.54 for the California dairy industry. Scott and Smith's (1986) study of the Pennsylvania dairy industry estimated short-run elasticities ranging between 0.04 and 0.26. Stonehouse et al. (1978) found short-run elasticities for fluid and industrial milk of 0.387 and 0.04 respectively. The supply price elasticity estimated in this study is for a blend of fluid and industrial milk.

The coefficient on provincial research expenditures [4] indicate that the effects of provincial research last from 2 to 12 years. Provincial research is often directed at the more applied areas such as forage cultivar testing or feeding, thus the short discovery-introduction lag is not unexpected. The long effective life of provincial efforts is unexpected, but also may be due to a combination of factors that go into the complete provincial support structure and cannot be specifically identified, such as extension and marketing activities.

The response to Canadian federal research expenditures is divided into two components, which may indicate the effects of basic and applied research. The short period response is first seen in the third year after the expenditures are made and continues for four years. In the eleventh year after expenditures are made, a second four-year effect begins. A long lag prior to discovery and adoption of more basic research is likely because of

[4] The coefficients attached to provincial research expenditures appear much larger than those for Canadian federal and United States expenditures. This is due to a difference in the units of measurement. Provincial expenditures are measured in millions of dollars and federal and U.S. expenditures expressed in thousands of dollars.

TABLE 1

Dairy supply function [a]

Explanatory variable	Coefficient	t-Statistic	Elasticity
Constant	14.26596	23.439	
Output price			
$(t-1)$:	0.10464	2.067	0.105
$(t-3)$:	0.10632	3.964	0.106
$(t-4)$:	0.07974	3.964	0.080
$(t-5)$:	0.05316	3.964	0.053
$(t-6)$:	0.02658	3.964	0.027
Total	−0.37044		0.370
Price of beef $(t-3)$:	−0.03854	−2.390	
Dairy cow inventory	1.97524	8.047	
Provincial research			
$(t-2)$:	0.00332	1.910	0.009
$(t-3)$:	0.00608	1.910	0.016
$(t-4)$:	0.00829	1.910	0.021
$(t-5)$:	0.00995	1.910	0.026
$(t-6)$:	0.01106	1.910	0.028
$(t-7)$:	0.01161	1.910	0.030
$(t-8)$:	0.01161	1.910	0.030
$(t-9)$:	0.01106	1.910	0.028
$(t-10)$:	0.00995	1.910	0.026
$(t-11)$:	0.00829	1.910	0.021
$(t-12)$:	0.00608	1.910	0.016
$(t-13)$:	0.00332	1.910	0.009
Total	0.10062		0.258
Canadian federal research			
$(t-3)$:	0.0000053	2.137	0.040
$(t-4)$:	0.0000079	2.137	0.059
$(t-5)$:	0.0000079	2.137	0.059
$(t-6)$:	0.0000053	2.137	0.040
$(t-11)$:	0.0000099	3.449	0.074
$(t-12)$:	0.0000150	3.449	0.112
$(t-13)$:	0.0000150	3.449	0.112
$(t-14)$:	0.0000099	3.449	0.074
Total	0.0000762		0.570
U.S. research			
$(t-4)$:	0.0000019	3.47536	0.100
$(t-5)$:	0.0000031	3.47536	0.162
$(t-6)$:	0.0000035	3.47536	0.183

TABLE 1 (continued)

Explanatory variable	Coefficient	t-Statistic	Elasticity
U.S. research			
$(t-7)$:	0.0000031	3.47536	0.162
$(t-8)$:	0.0000019	3.47536	0.100
Total	0.0000135		0.707
	Adjusted R^2:	0.944	
	Durbin–Watson:	2.54	
	F-Statistic:	45.26	

[a] Dependent variable: Milk equivalents in hectolitres.
Functional form: Partial-logarithmic.

the fundamental nature of the type of research undertaken. The relatively short effective life of the federal research may be partially a result of the period under consideration. This period has seen the discovery and adoP-tion of many new techniques with new discoveries coming very quickly. The cumulative elasticity of Canadian federal research expenditures is 0.570. Bredahl and Peterson (1976), using a production function approach, obtained a comparable elasticity of 0.538 for dairy research in the United States when their results are transformed to a supply function format.

United States research expenditures appear to take one year longer than the Canadian federal expenditures to be adopted by Canadian producers. The effective lag of these spillover effects is five years. The split effect exhibited by the Canadian federal variable was not found with the U.S. research. It may be that a longer time series would exhibit this effect, but the data were unavailable. It may also be that the spillover information of offshore basic research is adopted by Canadian researchers and further refined and tailored for use in the Canadian industry, thus the longer term effects are masked by this filtering process.

The supply elasticity of U.S. research expenditures is 0.707, larger than the elasticity of Canadian federal research expenditures. The U.S. research expenditures are used as a proxy for all foreign research activity that may have an effect on the Canadian dairy industry. It would appear reasonable that the volume of research performed on a world level would have a large impact on the domestic dairy industry through spill-in of discoveries that can be adopted and applied to Canadian dairy production systems.

ANALYSIS OF RESEARCH BENEFITS

Calculation of the annual gross benefits of research was performed through integration to obtain the relevant areas portrayed in Figs. 2, 3 and

4. The estimated supply functions indicate that the effects of federal research on the national output occurred from three to 14 years after research expenditure had been made. Research conducted between 1968 and 1984 would therefore generate benefits beginning in 1971 and ending in 1998. Average gross benefits are calculated for each year by comparing the position of the supply function when federal research expenditures were set at zero from 1968 to 1984 with the position of supply with historical values of research expenditures. All other technology shift variables and price variables are held at their actual levels. These gross benefits therefore are attributable to federal dairy cattle research. Net benefits are expressed as internal rates of return, net present values and benefit/cost ratios. All net benefits are calculated using 1968 as the starting point and are discounted for the net present values and benefit cost ratios using a 5% real discount rate. The selection of this discount rate is based on Kula (1984). Sensitivity analysis using real rates of 2% and 10% does not appreciably change the results reported below. Research costs used in the net benefit calculations are net of revenues generated from milk and meat sales from research institutes.

The demand function was assumed to be of the form:

$$Y = aP^{\eta} \tag{3}$$

where η is the demand elasticity at the farm level. The demand elasticity used was for a blended fluid and industrial demand for milk as calculated from data supplied from Agriculture Canada's FARM model (M. Cluff, Agric. Canada, Ottawa, Ont., Commodity Markets Analysis, personal com-

TABLE 2

Net benefits of Canadian federal dairy research, 1968–1998: Supply management scenario

		Real discount rate		
		2%	5%	10%
Average benefits				
Real internal rate of return	117.57%			
Net present value (constant 1981 Canadian million dollars)		18602.3	11113.2	5148.9
Ratio of benefits to costs		152.2	114.6	74.2
Marginal benefits				
Real internal rate of return	104.83%			
Ratio of benefits to costs		76.8	59.7	40.7

TABLE 3

Net benefits of Canadian dairy research, 1968–1998: Autarkic equilibrium scenario

		Real discount rate		
		2%	5%	10%
Average benefits				
Real internal rate of return	119.32%			
Net present value (constant 1981 Canadian million dollars)		19751.2	11722.0	5385.8
Ratio of benefits to costs		161.5	120.8	77.5
Marginal benefits				
Real internal rate of return	110.82%			
Ratio of benefits to costs		109.2	82.3	53.7

munication, 1988). The coefficient a was calculated for each year based on the actual quantity purchased from producers, the demand elasticity (-0.4) and the actual blend price paid to producers. This gave an equation for the farm level demand for milk for each year under consideration so that an equilibrium quantity and price could be calculated in conjunction with the estimated supply function.

Results for the supply management scenario are reported in Table 2. Estimates of what the returns to research would have been if supply management were not in operation and the intersection of domestic demand and supply determined prices (the Autarkic Equilibrium Scenario) are reported in Table 3. Under both scenarios, returns to research are high both on average and at the margin. The bias identified by Oehmke, namely that research returns could be substantially by the policy environment, does not seem to be important in this context. The distribution of research benefits between consumers and producers, however, is quite different under supply management (see Tables 4 and 5).

The sensitivity of the rate of return estimates to the marginal excess burden of taxes (see Fox, 1985) is reported in Table 6. A 20% marginal excess burden was assumed. [5] As one would expect, net benefit estimates declined, but the' magnitude of the decline is small enough to suggest that

[5] Stuart (1984), Ballard et al. (1985) and Browning (1976, 1987) have reported estimates of the marginal excess burden in the United States. Estimates are not presently available for Canada. For purposes of sensitivity analysis, a value of 20% was selected as representative of mid-range U.S. estimates.

TABLE 4

Distribution of benefits from Canadian federal dairy research, 1968–1998: Supply managed scenario

	Gross annual research benefits		Change in producers' surplus		Change in consumers' surplus	
	($ million)	% of total	($ million)	% of total	($ million)	% of total
Total (1971–1998)	27020.4	100.0%	(7153.6)	(26.5%)	34174.1	126.5%
Present value						
Real discount rate						
2%	18725.3	100.0	(5330.1)	(28.5)	24055.5	128.5
5%	11211.0	100.0	(3417.6)	(30.5)	14628.6	130.5
10%	5219.3	100.0	(1638.2)	(31.4)	6857.5	131.4

TABLE 5

Distribution of benefits from Canadian federal dairy research, 1968–1998: Autarkic equilibrium scenario

	Gross annual research benefits		Change in producers' surplus		Change in consumers' surplus	
	($ million)	% of total	($ million)	% of total	($ million)	% of total
Total (1971–1998)	28822.5	100.0%	(22447.4)	(77.9%)	51269.8	177.9%
Present value						
Real discount rate						
2%	19874.3	100.0	(15478.4)	(77.9)	35352.7	177.9
5%	11819.9	100.0	(9205.5)	(77.9)	21025.4	177.9
10%	5456.1	100.0	(4249.4)	(77.9)	9705.5	177.9

the marginal excess burden would have to be extremely large before investments in federal dairy cattle research would appear unattractive.

CONCLUSIONS

Net economic gains to the Canadian economy from federal dairy cattle research conducted between 1968 and 1984 amounted to approximately \$11.1 billion (10^9), measured in constant 1981 Canadian dollars taken as a net present value [6] at 1968. Simulation analysis indicated that these gains

[6] Based on a 5% real discount rate.

TABLE 6

Sensitivity of rate of return estimates to the marginal excess burden

	Base case		Including marginal excess tax burden in research costs [a]	
	Supply management	Autarkic equilibrium	Supply management	Autarkic equilibrium
Average Benefits				
Internal rate of return (%)	117.6	119.3	108.6	110.3
Benefit/Cost ratio [b]	114.6	120.8	93.0	98.0
Marginal Benefits				
Internal rate of return (%)	104.8	110.8	97.3	103.2
Benefit/Cost ratio [b]	59.7	82.3	50.2	68.6

[a] An excess burden of 20% was assumed.
[b] For a 5% discount rate.

would have amounted to about $11.7 billion if production quotas were not in place and the interaction of domestic supply and demand determined the price of milk as technological change shifted the national supply function. The use of production quotas and formula prices has reduced the rate at which the gains from technological change have been passed on to consumers by about 33%, but the realized gains by consumers have nevertheless been substantial. The current configuration of Canadian dairy policy has therefore reduced but not driven to zero the costs of technological change in primary production. Competition in the markets for quota in each province have provided an incentive for farms to adapt technological improvements in production practices. The absence of interprovincial redistribution of quota in response to changes in regional comparative advantage, however, have been one factor contributing to a less than complete realization of the gains from technological advance.

Our results suggest that technological change arising from research has reduced producers' surplus over time [7]. It should be emphasized, however, that all of the gains from research at the margin accrue to producers. This means that incremental reductions in the real rate of expenditure on dairy cattle research would reduce producers' surplus and have no effect on consumers. Reductions in consumers' benefits from research would only

[7] Recall, however, the Canadian dairy policy has induced an increase in producer welfare through income transfers from consumers and taxpayers (Barichello, 1981).

occur if research expenditure declined enough to cause the aggregate marginal cost function for the industry to intersect domestic demand above the formula price. Presently, the burden of funding agricultural research is borne by taxpayers, who, according to our results, could be seen as subsidizing consumers and producers who are the beneficiaries of research. Pressure on government expenditures in the interests of deficit reduction has led to the consideration of other means of financing agricultural research. Producer levies [8] represent one possible source of funds. Determination of an appropriate level of contributions by producers would entail an assessment of the net effects of product market distortions and research investments on producers. A critical element of such an assessment would be an appropriate characterization of the counterfactual undistorted product market equilibrium. [9]

REFERENCES

Agric. Canada, 1983. Genetic improvement program evaluation. Findings report, Program Evaluation Division, Audit and Evaluation Branch, Agriculture Canada.

Alston, J.M., Edwards, G.W. and Freebairn, J.W., 1988. Market distortions and benefits from research. Am. J. Agric. Econ., 70: 281–288.

Ballard, C.L., Shoven, J.B. and Walley, J., 1985. General equilibrium computations of the marginal welfare costs of taxes in the United States. Am. Econ. Rev., 75: 128–138.

Barichello, R.R., 1981. The economics of Canadian dairy industry regulation. Economic Council of Canada, Ottawa, Ont.

Barichello, R.R., 1984. Analyzing an agricultural marketing quota. Paper presented to the 4th Eur. Congr. Agricultural Economists, 3–7 September 1984, Kiel, Germany.

Bredahl, M. and Peterson, W., 1976. The productivity and allocation of research: U.S. Agricultural Experimental Stations. Am. J. Agric. Econ., 58: 684–692.

Browning, E.K., 1976. The marginal cost of public funds. J. Polit. Econ., 84: 283–298.

Browning, E.K., 1987. On the marginal welfare cost of taxation. Am Econ. Rev., 77, 11–23.

Chen, D., Courtney, R. and Schmitz, A., 1972. A polynomial lag formulation of milk production response. Am. J. Agric. Econ., 54: 77–83.

De Gorter, H. and Norton, G.W., 1988. The gains from research with price supports in U.S. Agriculture. Department of Agricultural Economics, Cornell University, Ithaca, NY.

Forbes, J.D., Hughes, R.D. and Warley, T.K., 1982. Economic intervention and regulation in Canadian agriculture, Economic Council of Canada, Ottawa, Ont.

Fox, G., 1985. Is the United States really underinvesting in agricultural research? Am. J. Agric. Econ., 67: 806–812.

Fox, G., Haque, A.K.E. and Brinkman, G.L., 1990. Product market distortions and the returns federal laying hen research in Canada: Reply and further results. Can. J. Agric. Econ., 38: 351–356.

[8] Agricultural research in Australia has been financed, in part, by producer levies.

[9] For further discussion of this topic, see Haque et al. (1989), Fox et al. (1990) and Lindner and Pannell (1990).

Guitard, A.A., 1985. The Canadian Agricultural Research Institution. In: K.K. Klein and W.H. Furtan (Editors), Economics of Agricultural Research in Canada. University of Calgary Press, Calgary, Alta.
Haque, A.K.E., Fox, G. and Brinkman, G.L., 1989. Product market distortions and the returns to federal laying hen research in Canada. Can. J. Agric. Econ., 37: 29–46.
Hunt, L., 1984. Sources of agricultural multifactor productivity change: an empirical investigation, Canada, 1961–1980. M.Sc. thesis, Univ. Guelph, Ont.
Kula, E., 1984. Derivation of the social preference rates for the United States and Canada. Q. J. Econ., 99: 873–882.
Lavigne, B. and Biggs, E., 1985. Report of the review committee on a long term dairy policy for Canada. Report to the Minister of Agriculture, Agriculture Canada, Ottawa, Ont.
Lindner, R.K. and Jarrett, F.G., 1978. Supply shifts and the size of research benefits. Am. J. Agric. Econ., 60: 48–58.
Lindner, R.K. and Pannell, D.J., 1990. Product market distortions and the returns to federal laying hen research in Canada: Comment. Can. J. Agric. Econ., 38: 345–350.
Oehmke, J., 1988. The calculation of returns to research in distorted markets. Agric. Econ., 2: 291–302.
Roberts, B.W., 1988. An analysis of the returns to Canadian federal government expenditures on dairy research between 1968 and 1984. M.Sc. Thesis, Univ. Guelph, Ont.
Rose, R.N., 1980. Supply shifts and the size of research benefits: Comment. Am. J. Agric. Econ., 62: 834–837.
Scott, D.R. and Smith, B.J., 1986. Estimates of milk supply response in Pennsylvania. Pa. State Bull. 857.
Stonehouse, D.P., 1987. A profile of the Canadian dairy industry and government policies. Agric. Can. Work. Pap. 4/87.
Stonehouse, D.P., Harrington, D.H. and Sahi, R.K., 1978. An econometric forecasting and policy analysis model of the Canadian dairy industry. In: Z.A. Hassan and H.B. Huff (Editors), Commodity Forecasting Models for Canadian Agriculture, Vol. 1. Agriculture Canada, Ottawa, Ont.
Stuart, C., 1984. Welfare costs per dollar of additional tax revenue in the United States. Am. Econ. Rev., 74: 352–362.
Wise, W.S. and Fell, E., 1980. Supply shifts and the size of research benefits: Comment. Am. J. Agric. Econ., 62: 838–840.
Zachariah, O.E.R., Fox, G. and Brinkman, G.L., 1989. Product market distortions and the returns to broiler chicken research in Canada. J. Agric. Econ., 40: 40–51.