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Abstract

The returns to Canadian federal sheep research expenditures between 1968 and 1984 are estimated using the economic surplus approach. Ex post and ex ante measures of the change in producers' surplus are compared. Regression analysis is used to estimate the lag structure of the effects of research on the national supply function, facilitating the estimation of returns on average and at the margin. The effect of the excess burden of tax collection on returns to sheep research was investigated. The internal rate of return to sheep research was found to be about 25% at the margin exclusive of the effects of the excess burden. This rate of return fell to 20% when the costs of an excess burden of 20¢ on the dollar was assumed.

I. Introduction

The purpose of this paper is to measure the net economic benefits of federally funded sheep research conducted in Canada from 1968 to 1984. The economic surplus model is used in the analysis. An adaptation of this approach makes possible the calculation of average as well as marginal net benefits.

Near unanimity has emerged among analysts who have estimated rates of return to agricultural research that net benefits of this form of public investment have been high.[1] Few studies, however, have focused on returns to livestock research, and only one previous study has investigated sheep research (Wennergren and Whitaker, 1977). Evaluation of the allocative efficiency of public investments in agricultural research is hampered by an absence of rate of return estimates for livestock research. Also, this paper investigates the impact of the excess burden on rates of return to research (see Fox (1985)).

II. Measurement of Research Benefits

Several approaches have been used to estimate the benefits of public agricultural research.[2] The economic surplus approach used in this study measures the benefits of research as the increase in consumers' surplus plus the net change in producers' surplus that occur when technological change generated by research expenditures shifts the industry supply function down and to the right. Canada is a net importer of lamb, mutton and wool. Since Canadian production and consumption comprise a very small proportion of world output and world trade, Canadian producers are assumed to face a perfectly elastic demand for their output. As a result, shifts in the domestic supply function induced by research have no effect on the price received by farmers and all of the benefits of research accrue to producers.

Biological lags in livestock production require farmers to commit resources to production before output prices are known. Production plans based on expected prices can appear to be sub-optimal *ex post* when evaluated with respect to realized prices. Producers' surplus can be measured on an *ex ante* basis using expected prices or on an *ex post* basis using realized prices and actual output levels (see Just *et al.* p. 251-254). Both approaches are used in this study to measure the change in producers' surplus as technology changes. *Ex ante* or expected producers' surplus is illustrated in Figure 1. S_1 is the actual supply function and S_0 is the supply function that would have existed had research not been undertaken. P_e is the expected price and P_r is the realized price. Expected producers' surplus is the area below P_e and above the supply function (panels (a) and (b)). As the supply function shifts, expected producers' surplus increases by the shaded area in panels (c) and (d). Note that the realized price, P_r, plays no role in the measurement of expected or *ex ante* producers' surplus.

In the *ex post* approach, expected price determines the level of output and the realized price is used to measure producers' surplus. Consider panel (a) of Figure 2. Q_0 is produced based on the expected price. The actual price, P_r, is less than P_e and producers' surplus is area g minus area c. Area c represents the extent to which variable costs exceed total revenues on the last $(Q_0 - Q_1)$ units of output. When the supply function shifts to S_1, producers' surplus becomes g + h + i + j (above S_1 and below P_r) - f (unrealized revenue from $Q_0^1 - Q_1^1$). The change in producers' surplus is g + h + i + j - f - (g - c). The net

Figure 1

The *Ex Ante* Approach to Measuring Changes in Producers' Surplus Under Technological Change

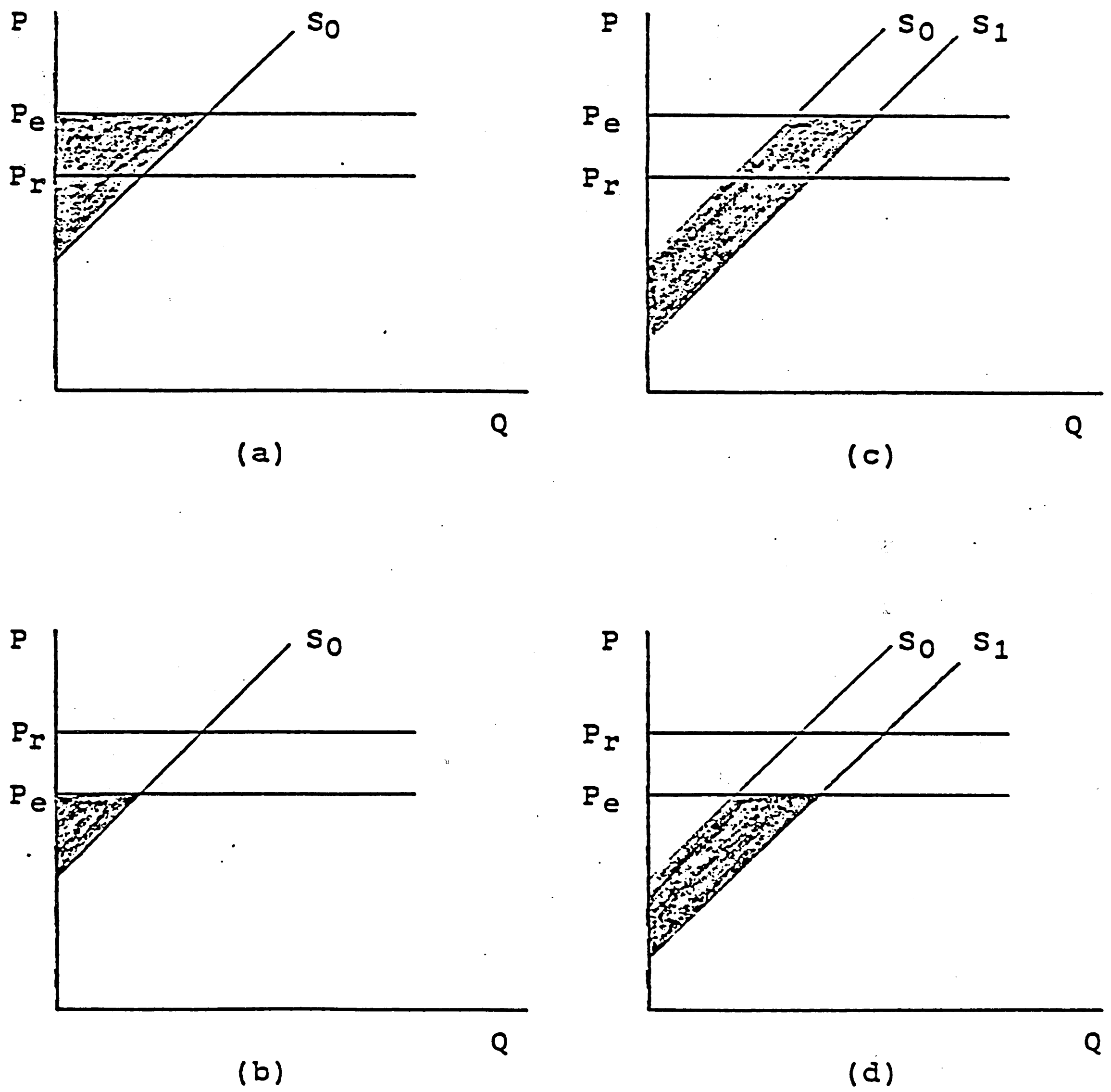
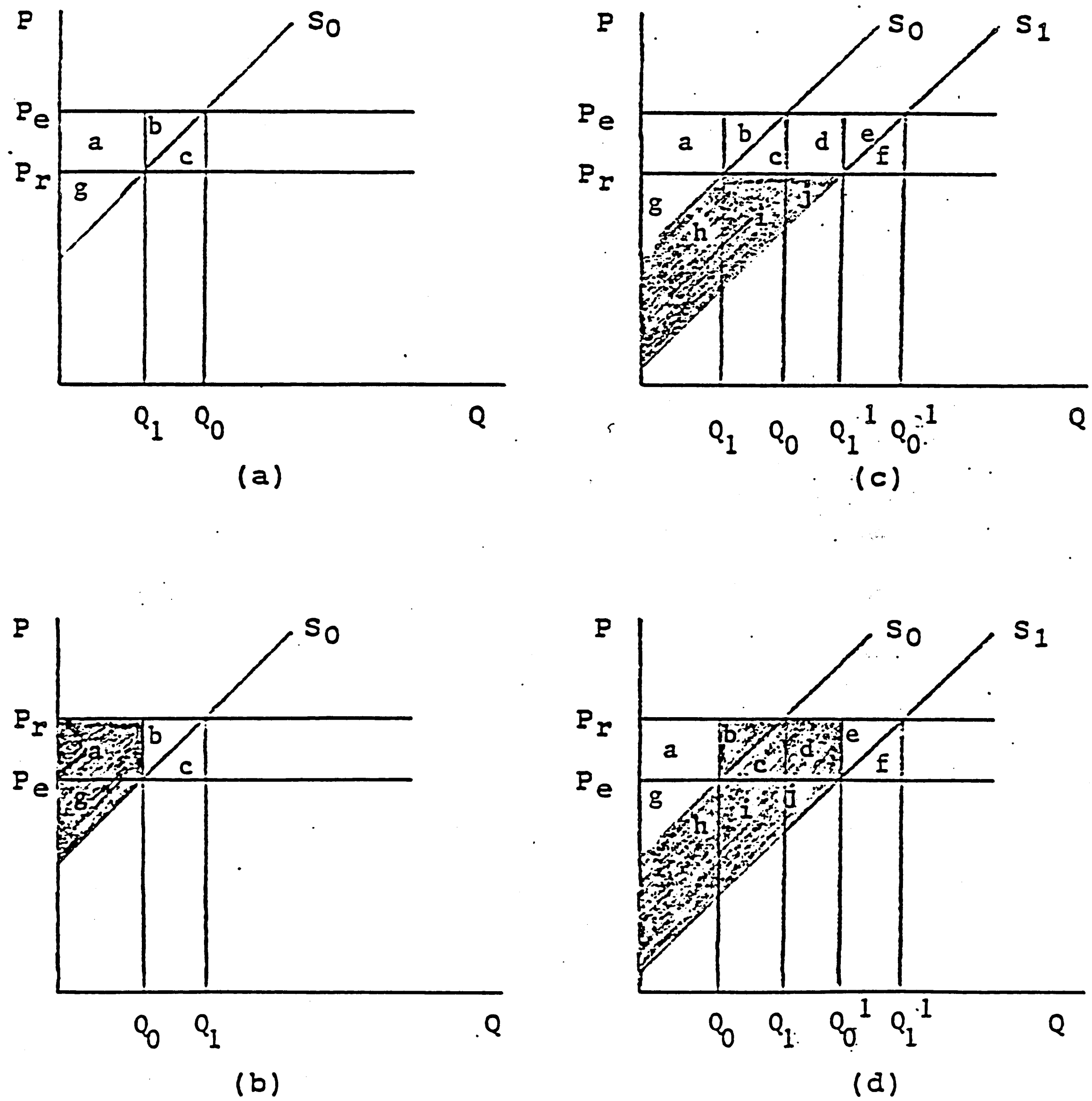


Figure 2

The *Ex Post* Approach to Measuring Changes in Producers' Surplus Under Technological Change



result is area h + i + j - f + c.[3]

In panel b), _ex post_ producers' surplus is a + g, when S_0 is the supply function and a + b + c + d + g + h + i + j when the supply function shifts to S_1. The change in producers' surplus is the shaded area b + c + d + h + i + j.

Traditionally studies employing the economic surplus approach to measure research benefits have used the rate of change in a productivity index to determine the rate of supply shift (see Peterson (1967) and Akino and Hayami (1975)). The type of supply shift (see Lindner and Jarrett (1978)) has been determined by assumption. In this study, the supply function was estimated using regression analysis using annual time series data. Canadian federal sheep research expenditures as well as provincial research and extension expenditures and sheep research expenditures from the United States are included among the set of explanatory variables along with the price of output and the price of feed. Direct estimation of the supply function forges an explicit link between research expenditures and the rate of shift, making it possible to calculate benefits from research at the margin (see Widmer _et al._ (1988)).

III. Estimation of the Supply Function

The supply function was estimated with Ordinary Least Squares (OLS) using annual time series data. OLS is an appropriate estimation technique in this context since all of the regressors are either predetermined or exogenous. All monetary values were converted to constant 1981 dollars using the GNE deflator. Annual data was used since research expenditures were reported annually. Coefficients of the estimated

Table 1

The Sheep Supply Function[1]

Dependent Variable: Lamb Equivalent, (Thousand Head)
Functional Form : Linear
Sample : 1954-1984, Annual Data

Explanatory Variable[3]	Coefficient	t-Statistic	Elasticity[2]
Lamb Price per Head (t-2)	2.689065	2.645032	0.33
Price of Hay (t-2) ($/unit)	-0.84012	-1.339993	-0.09
Price of Barley (t-2) ($/unit)	-0.57488	-2.345053	-0.18
Breeding Inventory (t-2) (thousand head)	1.366219	8.968877	1.30
Canadian Research			
t-3:	0.00952	2.09903	0.0473
t-4:	0.01429	2.09903	0.0710
t-5:	0.01429	2.09903	0.0710
t-6:	0.00952	2.09903	0.0473
Sum of Coeffs.:	0.04762	2.09903	0.2366
U.S. Research			
t-1:	-0.00013	-0.06558	-0.0046
t-2:	-0.00023	-0.06558	-0.0081
t-3:	-0.00029	-0.06558	-0.0103
t-4:	-0.00031	-0.06558	-0.0110
t-5:	-0.00029	-0.06558	-0.0103
t-6:	-0.00023	-0.06558	-0.0081
t-7:	-0.00013	-0.06558	-0.0046
Sum of Coeffs.:	-0.00161	-0.06558	-0.0569

Table 1 continued

Explanatory Variable	Coefficient	t-Statistic	Elasticity[2]
Index of Provincial Research and Extension (1981=100)			
t-1:	0.04684	1.76710	0.0604
t-2:	0.07494	1.76710	0.0966
t-3:	0.08431	1.76710	0.1086
t-4:	0.07494	1.76710	0.0966
t-5:	0.04684	1.76710	0.0604
Sum of Coeffs.:	0.32788	1.76710	0.4225
Education Index (1981=100)			
t-1:	-5.02161	-0.82205	-0.9100

Adjusted R-Squared:	0.971677
Durbin-Watson Statistic:	1.869054
F-Statistic:	113.7231

1 All monetary variables are expressed in constant 1981 dollars. Data used to estimate the supply function are reported in Fox et al. (1987) and Horbasz (1988) and are available from the authors on request.

2 Elasticities are evaluated at the sample means of the relevant variables.

3 The notation t-j indicates a lag length of j years.

supply function are reported in Table 1.[4]

Lindner and Jarrett (1978) have emphasized the importance of the type of shift in the industry supply function in determining the gross benefits generated by agricultural research. They concluded that most types of technological change observed in agriculture would either cause the supply function to shift in a parallel fashion or in a divergent proportionate manner. Efforts were made in the present study to estimate the type of supply shift by comparing alternative functional forms for the supply function. Following Widmer et al. (1988) a linear function and a partial logarithmic function were compared. The linear function was selected based on goodness of fit, the sign and significance of individual coefficients and on the properties of the residuals.

The dependent variable in the supply function is national annual output of lambs, mutton and wool aggregated to thousand head of lamb equivalents using relative prices. The lamb price is a national average farmgate price.

The major input in the production of the lamb is feed. The main components of feed are forages and grain. To represent the forage component, the annual price of hay in dollars per metric ton in Ontario was used (Agricultural Statistics for Ontario, Publication 20). A national weighted average price of hay was unavailable. Grain is fed to ewes during their final stages of pregnancy and sometimes to lambs in order to reach market weight. Barley is used as a proxy to describe the grain component of the feed. It is measured in annual average dollars per metric ton, basis in storage in Thunder Bay reported in Grain Trade of Canada (Statistics Canada, Cat. 22-201). The breeding inventory variable captures the constraint on lamb production imposed by the available stock of ewes.

Canadian federal research expenditures[5] include direct expenditures on sheep research under the Animal Productivity Research program, plus relevant operating costs, employee benefits, capital and grants and a prorated share of administration and support. In addition, a prorated share of public works expenditures for livestock research facilities in the national capital region are included. The cost of selected sheep disease research activities of the Animal Pathology Division which were considered to be complementary to the Animal Productivity Research program were also included.

United States swine research expenditures represent both federal and state expenditures. Sheep research expenditure data from 1968 to 1983 were obtained directly from the <u>Current Research Inventory System</u> (CRIS). Between 1959 and 1967, data from the U.S.D.A. appropriation hearings were used to estimate state and federal expenditures. Sheep research expenditure data for 1951 were obtained from Schultz (1953) and extrapolated to 1959 using an average growth rate. All data were converted into constant 1981 U.S. dollars by the index of prices paid by state and local governments for the purchase of goods and services (Economic Report of the President, 1986).

An index of provincial research and extension expenditures was constructed as the arithmetic mean of an index of provincial swine research expenditures and an index of provincial swine extension expenditures. The index of farmers' education levels is from Hunt (1984), updated with census data. Aggregate production oriented extension expenditures were obtained from Hunt (1984) for 1955 to 1980 for all provinces except Ontario, while 1955 to 1980 data for Ontario and 1981 to 1984 data for all provinces were obtained from provincial Public Accounts. Provincial production oriented extension expenditures were allocated to sheep using the share of gross farm sales in each province generated by sheep. Extension expenditures by province were then aggregated to obtain total provincial extension expenditures across Canada. Provincial agricultural research expenditures are based on the expenditures published in the Public Accounts of each province. Aggregate agricultural research expenditure from 1955 to 1980 for all provinces except Ontario were obtained from Hunt (1984), while 1955 to 1980 data for Ontario and 1981 to 1984 data for all provinces were obtained from Provincial Public Accounts. Sheep research expenditures were calculated by aggregating all provincial research expenditures and estimating the share allocated to sheep using the percentage share of man-years devoted to sheep research. The percentage share of man-years was available for selected years in the Inventory of Canadian Agricultural Research published by the Canadian Agricultural Research Council. Provincial support for research is limited in several provinces and provincial research and extension programs are closely related. Also provincial support for research and extension tends to be correlated with farmers' education over time, making it statistically difficult to estimate separate effects for these variables in a national supply function estimated with annual data.

The estimated own price elasticity of supply is somewhat higher than results reported by Tryfos (1974). A quadratic distributed lag with zero end points was found to give the best description of the effect of Canadian federal research expenditures on the domestic supply function. The hypothesis of zero end point constraints was not rejected at the 1%

level of significance (see Meilke (1975)). A lag length of 3 to 6 years is shorter than that reported for beef cattle research by Widmer et al. (1988), indicating that new technology is more readily adapted in sheep production than it is in beef production. The elasticity of domestic supply with respect to federal research (0.2366) is, however, only about one-half the value reported by Widmer et al. (1988) for beef cattle research, by Haque et al. (1987) for laying hen research or by Zachariah et al. (1988) for broiler research. U.S. research expenditures and education levels of farmers were found to have little effect on Canadian supply of sheep.

IV. Calculation of the Net Benefits of Sheep Research

The gross benefits of sheep research are calculated annually for the years 1971 to 1990.[6] S_0 in each year is derived by setting Canadian federal research expenditures equal to zero from 1968 to 1984, and by setting all other right hand side variables in the estimated supply function at their historical levels. S_1 is derived by setting research expenditures at their historical levels. The relevant changes in producers' surplus are calculated according to the approaches described in section II. Net returns are calculated by comparing gross returns with treasury costs less recoverable revenues.[7]

Returns to research at the margin are estimated by calculating the increase in producers' surplus that would have occurred had research expenditures been increased by 1% over the period in question. These gross returns are compared to the dollar value of a 1% increase in expenditure to derive an estimate of the returns to incremental changes in research funding.

Various formulas which approximate the change in welfare generated by research have been proposed in literature (see Peterson (1967), Akino and Hayami (1975)). In this paper, integration is used to calculate the exact change in the relevant producers' surplus. Net returns are reported in Table 2. The ex ante and ex post approaches produced similar results. This is in part attributable to the fact that the ex post approach collapses to the ex ante approach when benefits are calculated for years at the end of the simulation, since realized prices have not yet been observed. Rates of return at the margin are almost identical to the average rates of return.

V. Discussion

Using a real discount rate of 5%, each dollar spent on federal sheep research between 1968 and 1984 generated over $2.50 of benefits for sheep producers, measured as a present value in 1968. The estimated internal rate of return of approximately 25% is low compared to other areas of agricultural research (see Widmer et al. (1988), Haque et al. (1987) and Ruttan (1982, Chapter 10)), but sheep research has still been a profitable investment for the Canadian economy. The elasticity of the Canadian supply function with respect to federal research is low relative to values observed for beef cattle and poultry research, and expenditures on sheep research relative to revenues generated by the industry are high (see Fox et al. (1987), p. 12). This would suggest that efforts to improve the productivity of the sheep research program may be in order.

The impact of the excess burden of taxes is illustrated in Table 3. The actual size of the excess burden itself remains controversial (see

Table 2

Net Economic Benefits from Canadian Federal Sheep Research[1]

AVERAGE BENEFITS

Internal Rate of Return:	Ex Post:	25.31%
	Ex Ante:	24.23%

		Real Discount Rate 2%	5%	10%
Net Present Value:	Ex Post:	77.944	48.815	22.510
(Millions of $)	Ex Ante:	78.070	48.381	22.765
Benefit Cost Ratio:	Ex Post:	2.95	2.54	2.00
	Ex Ante:	2.94	2.51	1.96

MARGINAL BENEFITS

Internal Rate of Return:	Ex Post:	25.21%
	Ex Ante:	24.36%

		Real Discount Rate 2%	5%	10%
Benefit Cost Ratio:	Ex Post:	2.94	2.54	1.99
	Ex Ante:	2.95	2.53	1.97

1 All monetary values are measured in 1981 constant dollars.

Stuart (1984), Ballard et al. (1985) and Browning (1976, 1987)) and little is known about the excess burden generated by the Canadian tax system. An arbitrary value of 20¢ per dollar of tax revenue was assumed for the sensitivity analysis of Table 3. This was thought to be a conservative value based on results obtained for the United States. Internal rates of return to sheep research fell by about 25% when the excess burden was incorporated in the net benefit calculations. The resulting rate of return is comparable to the before-tax rate of return to capital in the private sector of the United States (see Fox, 1985), suggesting that the condition of chronic underinvestment usually thought to characterize public support for agricultural research may not hold for sheep research in Canada.

Table 3

The Impact of the Excess Burden on Returns to Sheep Research[1]

AVERAGE BENEFITS

Internal Rate of Return: Ex Post: 21.14%
Ex Ante: 20.46%

		Real Discount Rate 2%	5%	10%
Net Present Value:	Ex Post:	69.968	42.494	18.003
(Millions of $)	Ex Ante:	70.520	42.401	17.502
Benefit Cost Ratio:	Ex Post:	2.46	2.12	1.67
	Ex Ante:	2.47	2.12	1.65

MARGINAL BENEFITS

Internal Rate of Return: Ex Post: 20.02%
Ex Ante: 20.35%

		Discount Rate 2%	5%	10%
Benefit Cost Ratio:	Ex Post:	2.45	2.11	1.66
	Ex Ante:	2.46	2.11	1.64

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1 All monetary values are measured in 1981 constant dollars.

Footnotes

1 See Ruttan (1982, Chapter 10) and Carter _et al._ (1984) for reviews of selected studies.

2 See Brinkman (1983) and Fox (1987) for an overview.

3 Area f is equal to area c when the shift is parallel, the supply function is linear and demand is perfectly elastic. Therefore, the change in producers' surplus is the shaded area h + i + j.

4 Data used in the estimation of the supply function are reported in Fox _et al._ (1987) and are available from the authors on request.

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6 Given the lag structures for research estimated in the supply function, benefits from research conducted from 1968 to 1984 appear in the years 1971 to 1990.

7 Sheep flocks maintained for research purposes generate revenues which are remitted directly to the federal treasury. Actual budget costs of sheep research are reduced by these recoverable revenues.

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