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I. Introduction and Background

A substantial body of literature has indicated that public investments in agricultural research in most countries has generated high net social benefits[1]. Very few studies however, have formally acknowledged the impact of market distortions on the net benefits generated by research. Fox (1985b) has shown that the marginal excess burden of tax collection can have important consequences in the measurement of net social benefits of research. Little effort has been made, however, to include the effects of other types of distortions on net benefit calculations.

The purpose of this paper is to investigate the impact of distortions in the product market and the marginal excess burden of taxes on the magnitude and on the distribution of net benefits of public agricultural research. An extension of the economic surplus approach is used. Both average and marginal net benefits are computed. Federally funded egg research in Canada between 1968 and 1984 was selected for analysis. Federal and Provincial expenditures on egg research are reported in Figure 1.

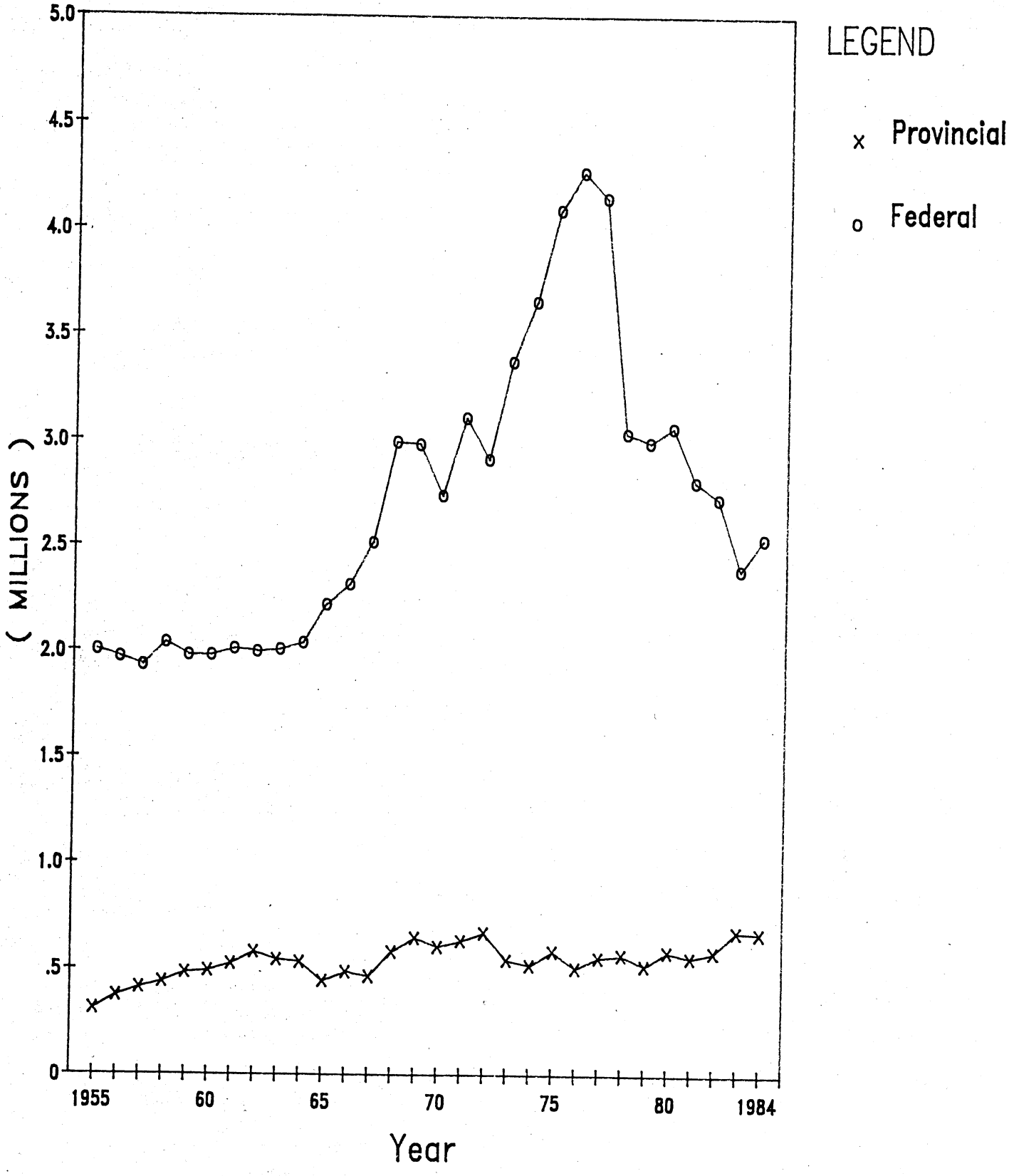
II. Market Structure and the Measurement of Research Benefits

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. The measure of the gross benefits of research is derived by comparing the actual supply function to the supply function that would have existed had the research not been undertaken. In the absence of distortions in the product market, as research shifts the supply function to the right price falls

Figure 1

EGG RESEARCH EXPENDITURES IN CANADA

(Constant 1981 Dollars)



and the quantity produced and consumed increases. In Figure 2, S_0 is the supply function that would have been observed if research had not been performed. S_1 is the actual supply function. As the market clearing price falls from P_0 to P_1, consumers' surplus increases by the area $P_1P_0\ E_0E_1$. At the same time, producers' surplus increases by $C_0\ B\ E_1\ C_1$, but this gain is offset by the area $P_1P_0\ E_0\ B$. 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. The net gain to the economy is the area $C_1C_0\ E_0E_1$.

Since 1974, the Canadian Egg Marketing Agency (CEMA) has regulated national egg production in Canada through the use of quotas allocated to provinces and subsequently to individual producers.[2] The price of output is determined on the basis of a "cost of production" formula, and the national quota is adjusted to satisfy expected demand at this price. Departure from the market clearing equilibrium price and quantity that would prevail in the absence of a quota imposes a deadweight loss on society. This loss is shown as the shaded area in Figure 3a.

The imposition of a quota in the product market reduces the gross benefits from research. In Figure 3b, gross benefits are the shaded area $C_0\ B\ D\ C_1$, rather the $C_0\ E_0E_1\ C_1$. Since the formula price P_F is not determined by the interaction of supply and demand, shifts in the supply function induced by research do not confer any benefits on consumers. If the shift in the supply function is sufficiently large, and/or 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 Figure 3c. In this situation,

Figure 2

Measuring the Gross Annual Benefits from Research in the Absence of Product Market Distortions

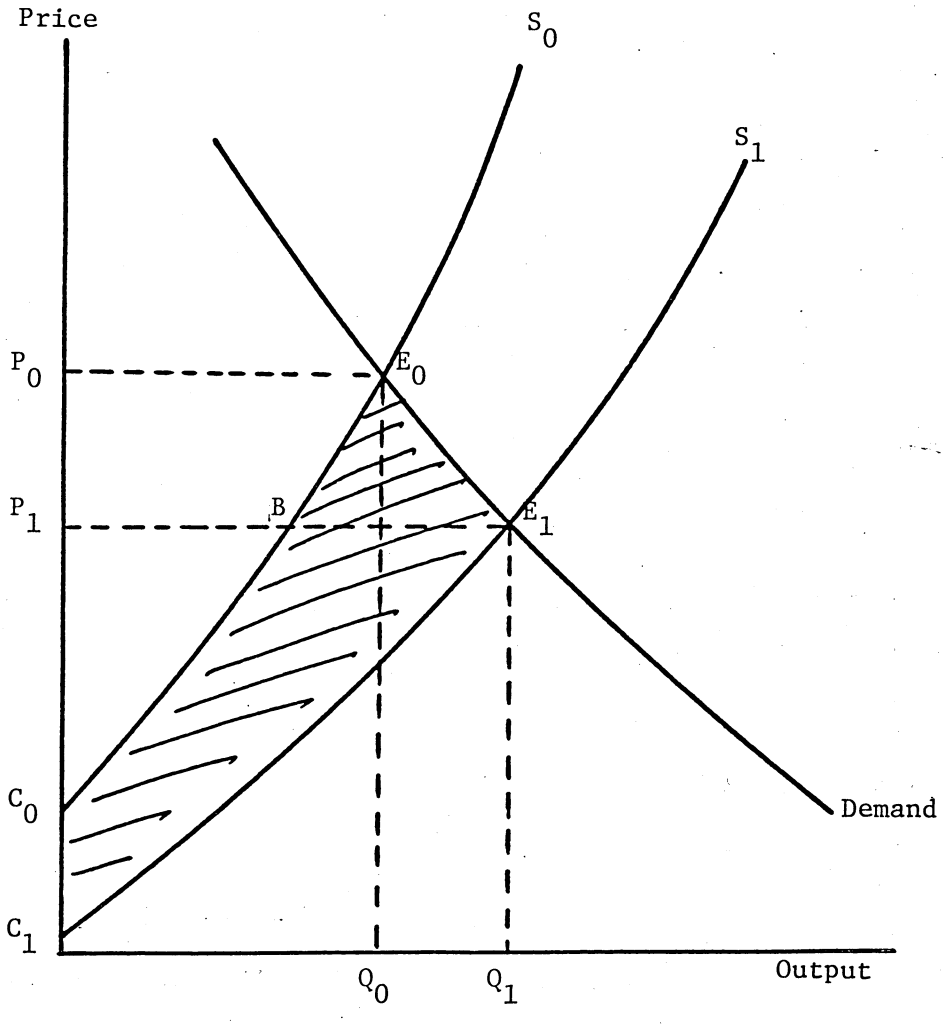


Figure 3a

The Welfare Costs of an Output Quota with a Formula Price

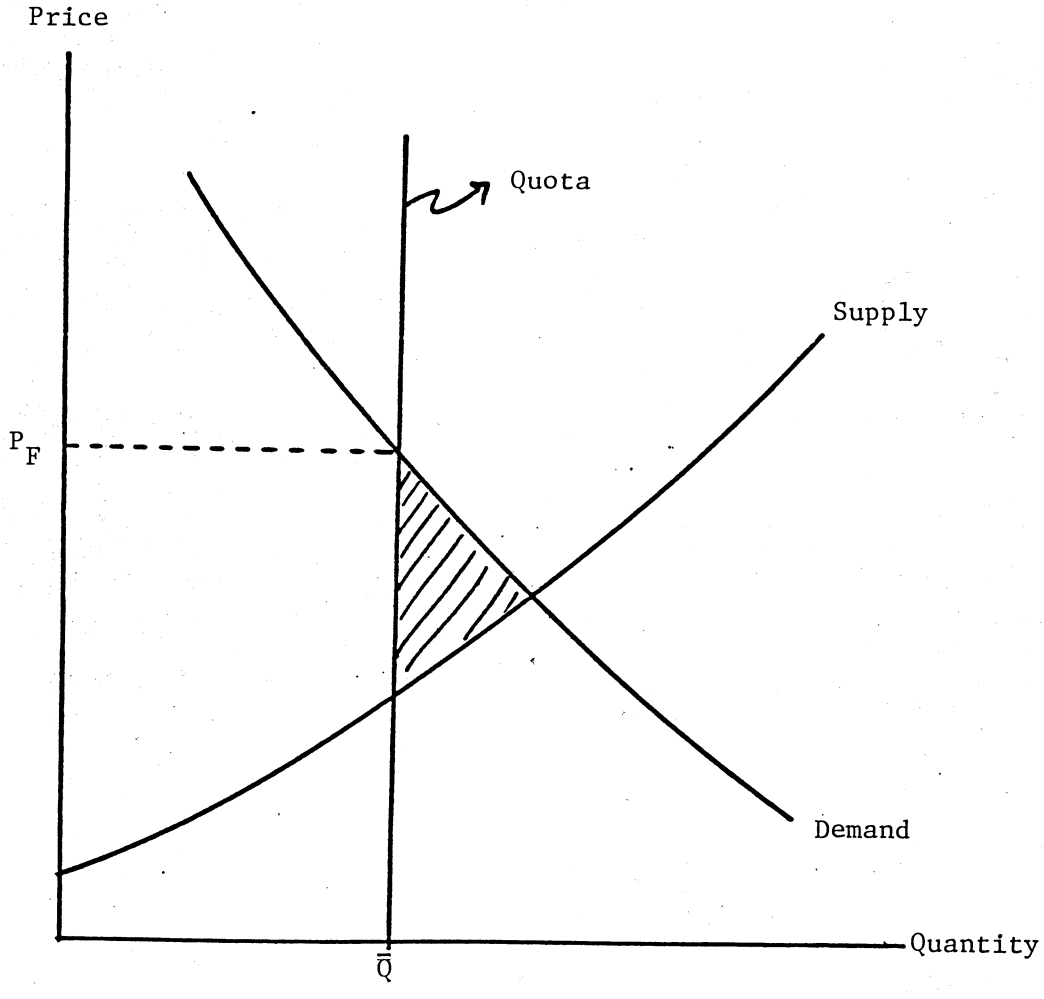


Figure 3b

Gross Gains from Research with an Output Quota - Case 1

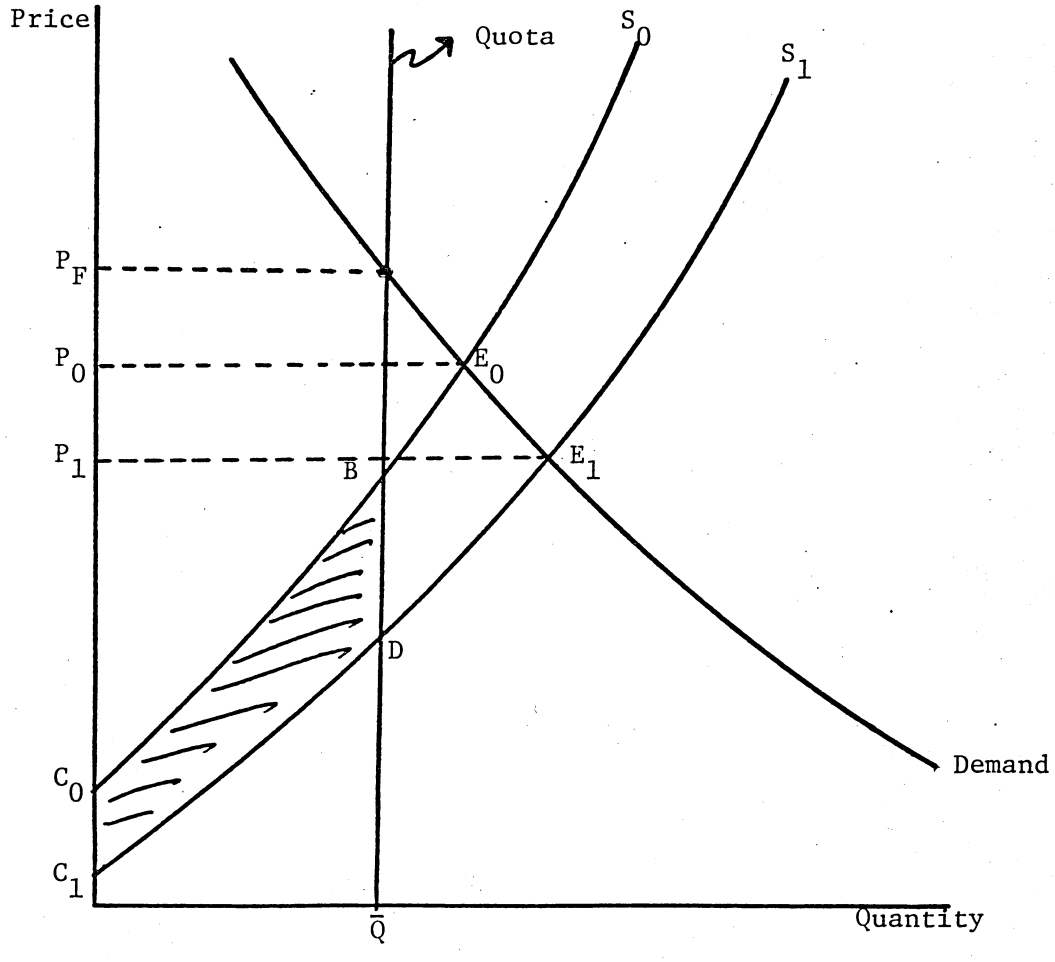
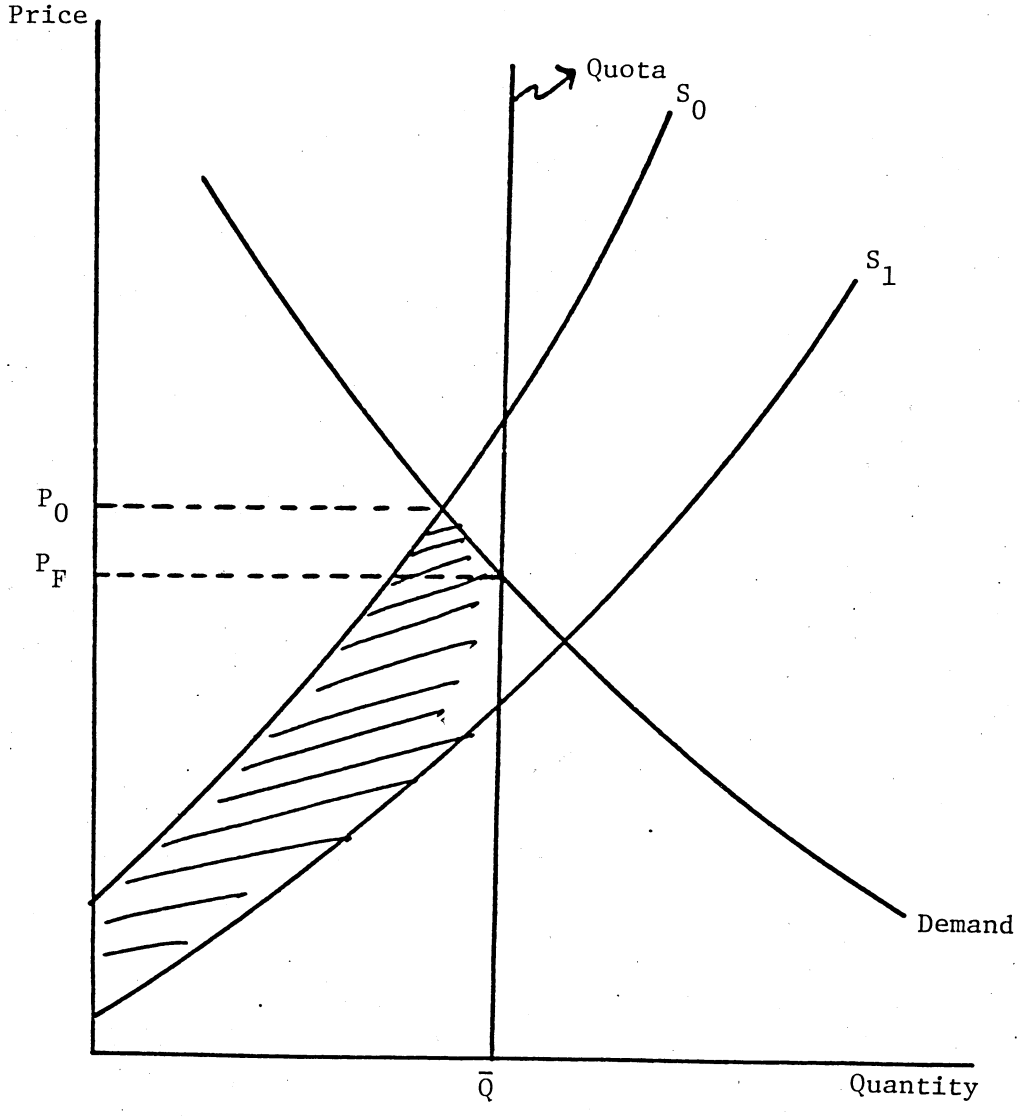


Figure 3c

Gross Gains from Research with an Output Quota - Case 2



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.

Traditionally, the rate at which the supply function shifts has been estimated from changes in a single-factor or a multi-factor productivity index.[3] The manner in which the supply function shifted along its length was determined by assumption. Lindner and Jarrett (1978) have shown that estimates of net benefits are sensitive to the types of supply shift assumed. This has been a major limitation of the economic surplus approach. Also, the use of a productivity index to estimate the rate of the supply shift does not provide an explicit link between the level of research expenditure and the rate of the shift. This means that only average benefits can be evaluated. Measurement of net benefits at the margin are needed to evaluate the efficiency of the allocation of public research resources.

The supply function is estimated directly in this study and lagged values of relevant research expenditures included as explanatory variables. Two functional forms for supply were compared. A linear function,

$$Q^S = a + bP - cW - h(R)$$

where Q^S is the quantity supplied, P and W are the prices of output and input respectively, and R is a vector of lagged research expenditures and other technology shifters, generates a parallel shift in the supply function. A partial logarithmic function,

$$Q^S = aP^{\eta} W^{\varepsilon} e^{h(R)}$$

which is linear in logarithms, generates a divergent proportionate shift. These two types of shift were identified by Lindner and Jarrett

as being of most empirical relevance.

Returns to research at the margin are estimated by comparing the position of the actual supply function in a particular year (S_1) with the supply function that would have existed if research funding had been increased by 1% in each year from 1968 to 1984. 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 to the dollar value of the 1% increase in funding to calculate net benefits.

Intervention in the market for eggs 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. In order to estimate the impact of product market distortions on the net benefits of research and on the distribution of those benefits, gross benefit calculations were performed for three separate scenarios. The first scenario represents the actual level of research benefits obtained under supply management, assuming that the instruments[4] used to regulate output and price are in place from 1974 until the last year in which research performed in 1984 would be estimated to influence national supply. The second scenario estimates the benefits that would have been generated by egg research if there had not been output controls but a closed border was maintained. Egg prices and output levels then depend on the interaction of domestic supply and demand. In the third scenario, benefits are estimated for the situation with no output controls and with an open border with the United States. Canadian

producers are assumed to face a perfectly elastic demand for eggs at the U.S. price. This assumption is based on the fact that Canadian egg output constitutes a small proportion of total North American output.

III. Estimation of the Supply Function

Estimates of the parameters of the supply function are reported in Table 1.[5] A linear function was found to give a more reasonable fit to the data in our sample than did a partial-logarithmic function, indicating that research has contributed to a parallel shift in the supply function for eggs. The supply function was estimated with annual time series data using Ordinary Least Squares, since all of the right-hand side variables can be considered pre-determined or exogenous to the decisions of egg producers. All of the coefficients, with the exception of the dummy variable, were estimated as polynomial distributed lags. The Canadian federal and U.S. research expenditure coefficients were estimated as quadratic distributed lags with zero constrained end points, following the approach used by Cline (1975).[6] The dummy variable reflects the structural change in the national supply functions after the introduction of supply management with the Canadian Egg Marketing Agency (CEMA). Since the function was estimated using annual data, the CEMA dummy variable begins in 1974, the first full calendar year of supply management.

When intervention is imposed in the product market in the form of supply management, the observed commodity price is not a marginal cost price. It is a combination of marginal resource costs and economic rent accruing to the production control instrument. If an annual rental value for producer quotas could be obtained, then this could be deducted

Table 1
The Supply Function for Eggs in Canada

Dependent Variable: Million Dozen Eggs
Functional Form : Linear
Sample : 1963-1984

Explanatory Variables	Coefficients	t-statistic	Elasticity*
Price of Eggs**			
t-1 (Cents per dozen)	1.302	3.345	0.244
t-2	0.868	3.345	0.163
t-3	0.434	3.345	0.081
Sum of Coefficients	2.604	3.345	0.488
Price of Laying Mash**			
t-1 (Cents per kg.)	-2.444	-2.079	
t-2	-1.833	-2.079	
t-3	-1.222	-2.079	
t-4	-0.611	-2.079	
Sum of Coefficients	-6.110	-2.079	
Provincial Research Expenditures on Eggs**			
t-1	25.185	0.772	0.031
t-2	20.987	0.772	0.026
t-3	16.790	0.772	0.021
t-4	12.592	0.772	0.015
t-5	8.395	0.772	0.010
t-6	4.197	0.772	0.005
Sum of Coefficients	88.148	0.772	0.108
Federal Egg Research Expenditures**			
t-3	9.337	6.241	0.058
t-4	15.563	6.241	0.097
t-5	18.675	6.241	0.117
t-6	18.675	6.241	0.117
t-7	15.563	6.241	0.097
t-8	9.337	6.241	0.058
Sum of Coefficients	87.151	6.241	0.544
US Egg Research Expenditures			
t-3	0.579	3.114	0.036
t-4	0.965	3.114	0.061
t-5	1.158	3.114	0.073
t-6	1.158	3.114	0.073
t-7	0.965	3.114	0.061
t-8	0.579	3.114	0.036
Sum of Coefficients	5.460	3.114	0.340
CEMA Dummy	-102.645	-6.936	
Adjusted R-Squared	0.708		
Durbin-Watson Statistic	1.823		
F-Statistic	11.203		

* All elasticities have been calculated at the mid point of the sample.
** All Canadian monetary values have been converted to constant 1981 dollars using the GNE deflator.

from the observed price to obtain the marginal cost of output at the quota. Unfortunately, quotas can only be transferred among producers as part of the sale of all of a farm's assets, so it is not possible to separate the value of quota from the value of other assets. In the absence of a quota rental adjusted Canadian price, the U.S. farm price of eggs was used in the supply function from 1974 to 1984. Prior to 1974, the Canadian price of eggs was 12% lower on average than the U.S. price converted to Canadian currency, so 88% of the U.S. price was used as the price variable in the supply management years.

The estimated function displays a relatively inelastic response to price. Interpreting the elasticity with respect to the sum of the coefficients as a long run elasticity, a sustained 1% increase in price leads to a 0.488% increase in output after 3 years. The effect of provincial research on the supply function was found to be positive but statistically weak, as indicated by the t-statistics. Canadian federal research began to shift the industry supply function after three years, and the effect of research had dissipated by the ninth year. Cline (1975) and Evenson (1968) found that research lays were as long as 13 years when U.S. agriculture was treated as a single sector. The shorter lag observed here at the industry level is consistent with the notion that changing technology and improved genetic potential can be adapted more quickly in egg production since the productive life of the laying hen is relatively short. The long-run elasticity of the supply function with respect to Canadian federal research was estimated to be 0.544. Finally, a significant spill-in effect from laying hen and poultry research from the United States was observed. Apparently, technology transfer across the border has been an important factor in the evolution

of the Canadian industry.

IV. Calculation of the Net Benefits of Research

The estimated supply function indicates that Canadian federal egg research has affected national supply from three to eight years after the research expenditure was made. Research conducted between 1968 and 1984 would therefore generate gross benefits beginning in 1971 and ending in 1992. Gross research benefits are calculated for each of these years using the procedures described in section II for each of the three scenarios. Areas representing the monetary value of welfare change are evaluated by integration.

Livestock research typically requires that a population of animals be maintained on the experiment station. These animals produce meat, eggs and other products which are sold. These sales, called recoverable revenues henceforth, can be considerable. In 1985, recoverable revenues from federal egg research amounted to about 4% of the total budgetary cost of egg resarch in Canada. These revenues are remitted directly to the federal treasury, and are not reflected in the budgets of agencies responsible for egg research. As a consequence, the net social cost of research is actually less than the apparent budget cost. Nevertheless, it is the size of the budget that determines the size of the research effort, in terms of personnel, buildings and equipment. To accommodate this institutional anomaly, the budget cost of egg research was used as the data series in the estimation of the supply function, since presumably the overall size of the research effort would determine the magnitude of the supply shift. Budget costs of research less recoverable revenues were used to compute the net benefits of research, however,

since it is this adjusted value that represents the net cost to the federal treasury.

Implementation of the economic surplus approach to measuring gross benefits of research requires the specification of a demand function. This should be a derived or farm level, as opposed to a retail demand function.[6] Estimates of the retail demand elasticity were taken from the literature and used in conjunction with an estimated marketing margin equation to compute a derived demand elasticity for each year (See Haque for details).

Table 2 reports the average net benefits from Canadian federal egg research for the period 1968-1984. Each of the three measures of net benefit indicate that these research expenditures generate substantial net gains for the Canadian economy. Net benefits for the supply management and the closed economy scenarios are almost identical indicating that product market distortions in this situation did not lead to a substantial reduction in the net benefits from research. Marginal benefits (Table 3) are slightly higher than the average benefits for the supply management and closed economy scenarios, and slightly lower for the open economy model.

Net benefits of research are actually lower for the open economy scenario than for the two closed economy versions of the model. In the open economy case, shifts in the Canadian supply function have no effect on the price of eggs in Canada. This means that research does not generate any benefits for Canadian consumers. Changes in consumers' surplus from falling prices in the closed economy scenarios contribute substantially to the difference in net benefits between the open and closed economy models.

Table 2

Measures of Average Net Benefits from Egg Research*

Measures of Benefits	Real Discount Rate 2%	5%	10%
Net Present Value ($ million)			
Supply Management	3886.9	2649.9	1484.6
Closed Economy	3902.9	2660.2	1489.9
Open Economy	2468.6	1692.0	959.6
Benefit Cost Ratio			
Supply Management	93.6	78.4	59.1
Closed Economy	94.0	78.7	59.3
Open Economy	59.8	50.4	38.5
Internal Rate of Return			
Supply Management	124.1%		
Closed Economy	124.2%		
Open Economy	115.6%		

* All calculations are made in constant 1981 dollars.

Table 3

Measures of Marginal Net Benefits from Egg Research*

Measures of Benefits	Real Discount Rate 2%	5%	10%
Marginal Net Present Value ($ million)			
Supply Management	48.9	33.2	18.4
Closed Economy	48.9	33.2	18.4
Open Economy	20.1	13.7	7.8
Benefit Cost Ratio			
Supply Management	117.5	97.8	73.0
Closed Economy	117.5	97.8	73.0
Open Economy	48.8	40.9	31.3
Marginal Internal Rate of Return			
Supply Management	130.6%		
Closed Economy	130.6%		
Open Economy	114.7%		

* All calculations are made in constant 1981 dollars.

Table 4

Average Net Benefits of Canadian Egg Research Adjusted for the Marginal Excess Burden of Taxation*

Measures of Benefits	Real Discount Rate 2%	5%	10%
Net Present Value			
Supply Management	3877.7	2642.4	1479.0
Closed Economy	3893.6	2652.6	1484.2
Open Economy	2459.4	1684.5	954.0
Benefit Cost Ratio			
Supply Management	76.7	64.3	48.4
Closed Economy	77.0	64.5	48.6
Open Economy	49.0	41.3	31.6
Internal Rate of Return			
Supply Management	115.9%		
Closed Economy	116.0%		
Open Economy	107.5%		

* All calculations made in constant 1981 dollars.

Table 5

Marginal Net Benefits of Canadian Egg Research
Adjusted for the Marginal Excess Burden of Taxation*

Measures of Benefits	Real Discount Rate 2%	5%	10%
Net Present Value ($ million)			
Supply Management	48.8	33.1	18.3
Closed Economy	48.8	33.1	18.3
Open Economy	19.9	13.5	7.7
Benefit Cost Ratio			
Supply Management	96.2	80.1	59.8
Closed Economy	96.2	80.1	59.8
Open Economy	39.9	33.5	25.6
Internal Rate of Return			
Supply Management	122.8%		
Closed Economy	122.8%		
Open Economy	105.9%		

* All calculations are made in constant 1981 dollars.

When the marginal excess burden is added to the costs of public research, net benefits fall (Table 4 and 5). The average interal rate of return for benefits realized under supply management fell by about 7%. The benefit cost ratio for a real discount rate of 5% fell by about 22%. Even net of the marginal excess burden of taxes, however, net benefits of egg research in Canada are high, with benefit-cost ratios for average benefits ranging from 41.3 to 64.3 to one for a real discount rate of 5%.

The institutional setting in which price and quantity are determined in the product market had only a minor effect on the magnitude of net benefits of research, but it was found to play a very significant role in how those benefits are distributed among producers and consumers (Table 6). Under supply management, about 90% of the total benefits of research accrue to consumers. Figure 4 shows that producers are actually made worse off by research prior to the institution of supply management in 1974. This occurs because of the extremely inelastic domestic demand function. As research shifts the supply function, reduction in the price of eggs reduces total revenue and producers' surplus falls. This situation is repeated throughout the closed economy scenario (Figure 5). Producers gain all of the benefits from research in the open economy scenario, but they acquire this gain at the expense of a lower output price. Arcus estimated that the annual income benefits of supply management for Canadian egg producers were about $45 million in 1980. It would appear that the potential gains available to producers if they could fully exploit the technology generated by federal agricultural researchers in an open North American market are larger than the income transfer they presently receive as a result of intervention in the

Table 6

The Distribution of Average Net Benefits* of Egg Research in Canada 1968-1992

	Total Gross Benefits		Gains to Consumers		Gains to Producers	
	(Value)	% of Total	(Value)	% of Total	(Value)	% of Total
Average Annual Benefit						
Supply Management	234.1	100	208.0	90.7	26.1	9.3
Closed Economy	235.1	100	269.7	130.7	-34.6	-30.1
Open Economy	149.1	100	0.0	0	149.1	100.0
Present Value (5% Real Discount Rate)						
Supply Management	2684.2	100	2403.7	90.0	280.5	10.0
Closed Economy	2694.4	100	3055.8	113.4	-361.4	-13.4
Open Economy	1726.2	100	0.0	0.0	1762.2	100.0

* All calculations are made in million constant 1981 dollars.

Figure 4

DISTRIBUTION OF EGG RESEARCH BENEFITS

SUPPLY MANAGEMENT SCENARIO

(Constant 1981 Dollars)

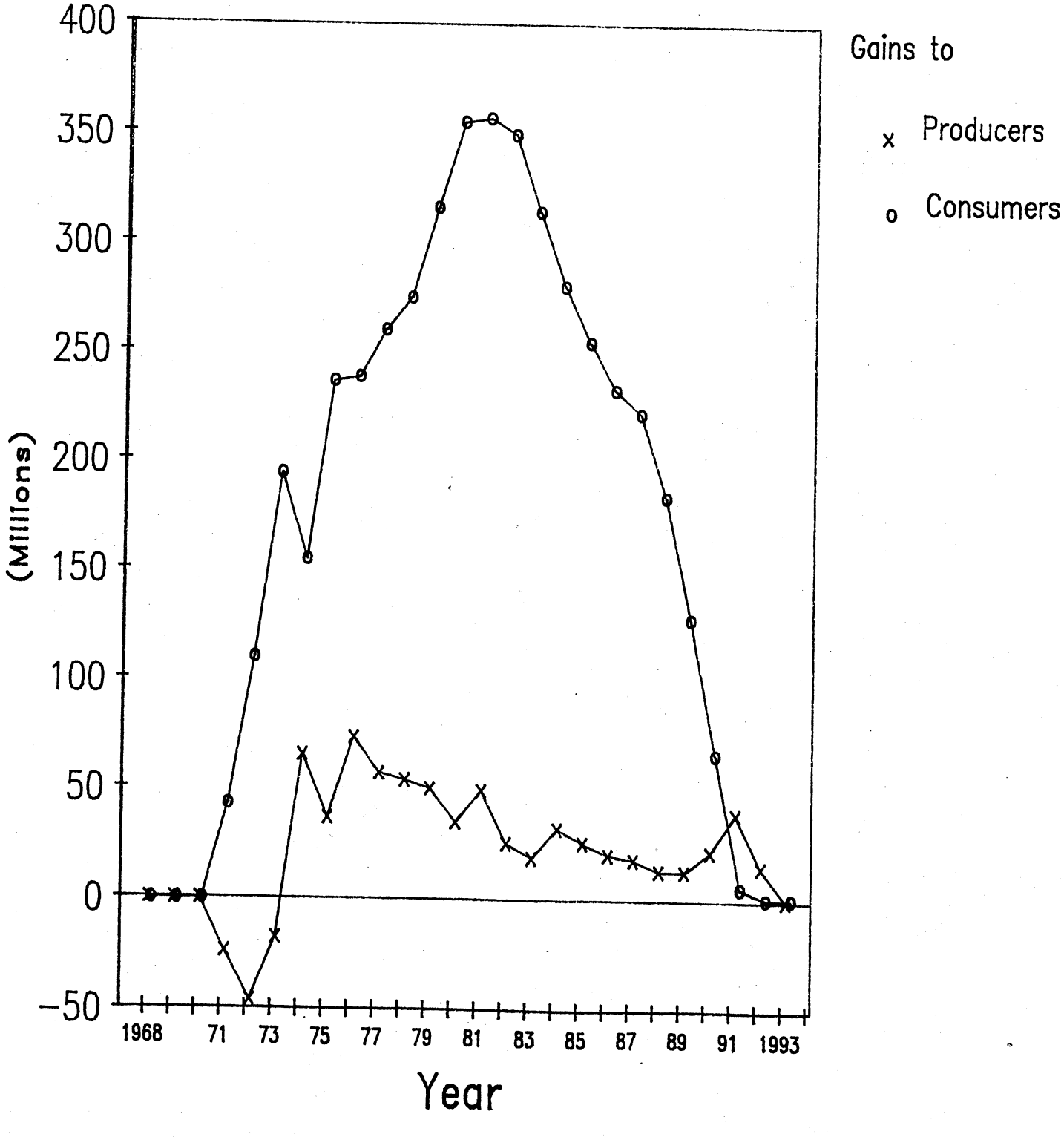
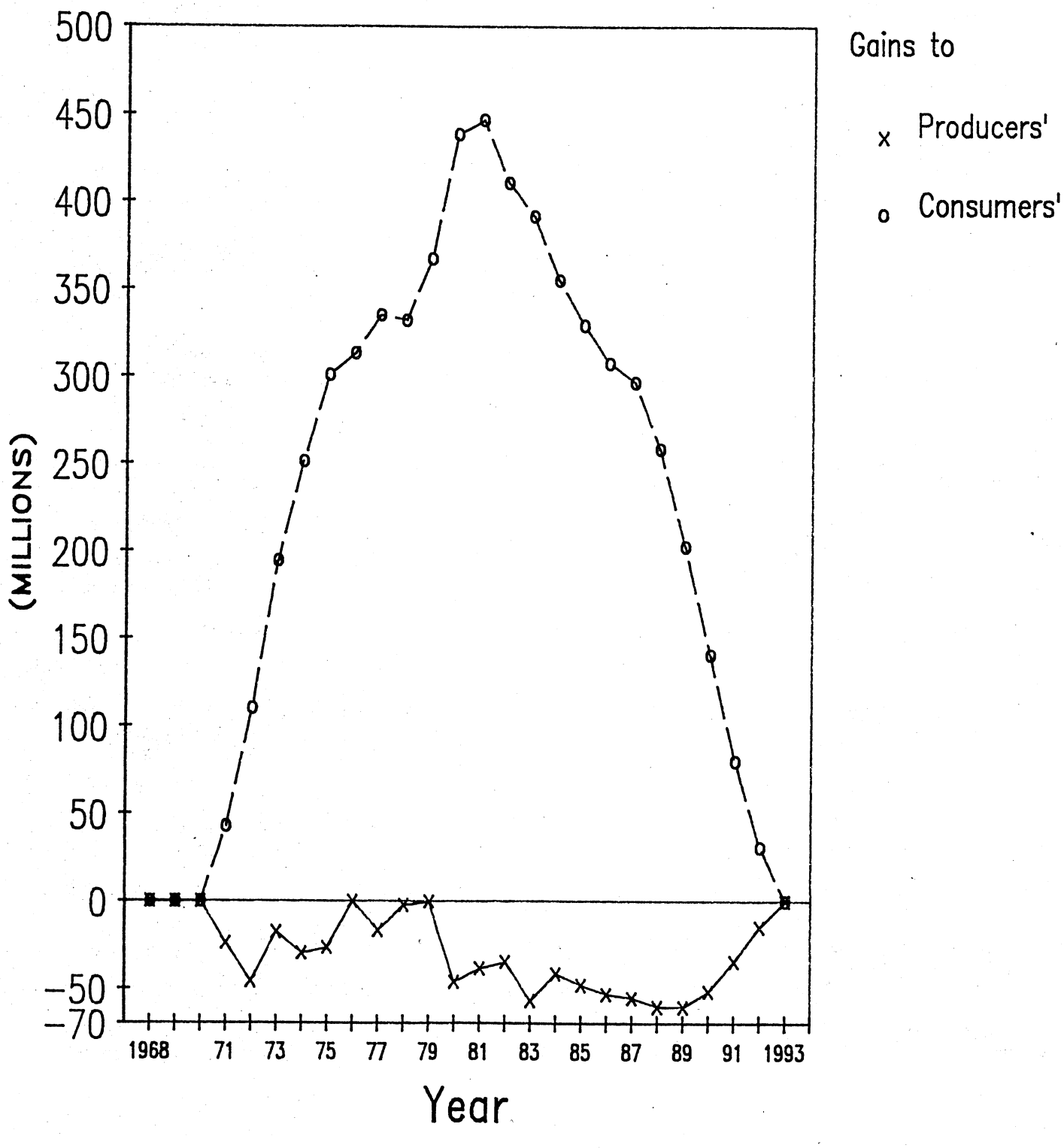


Figure 5
DISTRIBUTION OF EGG RESEARCH BENEFITS
CLOSED ECONOMY SCENARIO
(Constant 1981 Dollars)



product market.

V. Discussion

Most attempts to estimate net social benefits of agricultural research have focused on crop research or on overall research systems. Relatively few studies have estimated rates of return to livestock research. Exceptions to this generalization are Peterson (1967), Bredahl and Peterson (1976) and Fox (1985a). The present study and five companion studies[8] are intended to add to this presently thin literature.

Net benefits from federal egg research in Canada were found to be high. Distortions in the product market were found to have a small impact on the magnitude of net benefits generated by research, but had a very significant impact on the distribution of those benefits. The estimated rates of return are indicative of underinvestment in egg research, even when the marginal excess burden is included in the net benefit calculations.

Footnotes

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1 See Ruttan (1982, Chapter 10) or Pinstrup-Anderson (1982) for a survey of this literature.

2 For a detailed discussion of the economics of this scheme see Borcherding (1981), Forbes, Hughes and Warley (1982) and Arcus (1981).

3 See Peterson (1967) and Akino and Hayami (1975).

4 Supply management in Canadian egg production is accomplished through the use of three instruments: a formula price, national, provincial and farm level output quotas and a closed border.

5 For detailed definitions for each of the variables in the supply function, see Haque (1987).

6 A statistical test was performed on the zero constraints and it failed to reject the hypothesis that zero constrained end points for the federal research expenditures were appropriate at 1% level of significance. Similar tests for other end point constraints also failed to reject similar hypotheses at 1% level.

7 Since the estimated supply function was found to be linear, a linear farm level demand function was assumed.

8 Estimates of the rate of return to research on other livestock commodities in Canada is presently underway at the University of Guelph.

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