ENERGY AND NON-ENERGY INPUT SUBSTITUTION POSSIBILITIES AND ITS APPLICATION TO MEASURE THE IMPACT OF NATIONAL ENERGY PROGRAM ON FARM INCOME IN CANADA*

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Introduction

Continuous increases in world crude oil prices prompted the Canadian government, after lengthy discussions with the provinces, to implement a new national energy program which would allow the oil price in Canada to gradually increase from the present level to a maximum of 75 percent of the average world price during the period 1981 to 1986. This rapidly rising price of energy, resulting from a combination of institutional and market forces, is expected to have a significant influence on the structure of input demand and production costs in the Canadian agricultural industry.

The substitution possibilities between energy and non-energy inputs becomes particularly important if one is interested in deriving the impact of increasingly higher priced energy and energy-based inputs on the welfare of the producers. The smaller the possibilities for substitution between energy and non-energy inputs the more difficult one might expect the adjustment by the industry to higher energy prices to be. Unit costs may rise faster and the composition of output may have to shift away from energy intensive products. This could require significant changes in the underlying technological structure.

Another important aspect not usually considered in impact analyses is the effect of expanding the scale of production on energy efficiency. Since Canadian farm production is expected to expand quite rapidly during the foreseeable future, it is important that such scale effects associated with energy price increases be considered in the analysis.

Recent studies by Lopez and Tung [3] and Lopez [4] indicated that in the Canadian agricultural industry (a) substitution possibilities exist between energy and non-energy inputs; (b) energy and energy-based inputs appear to be complements; and (c) the output scale has significant effects on production costs and on the responsiveness of input to price changes.

The purpose of this paper is to investigate the short and long-run impacts of the national energy program on the welfare of Canadian farmers as measured by net farm income. The study uses a simulation model which emphasizes substitution possibilities and the output scale effect on the responsiveness of input use to price change. This paper focuses on the analysis of the results as well as on their potential policy implications.

Model Specification

The basic framework of the study is an econometric simulation model. The model considers the interactions between input prices and input utilization in

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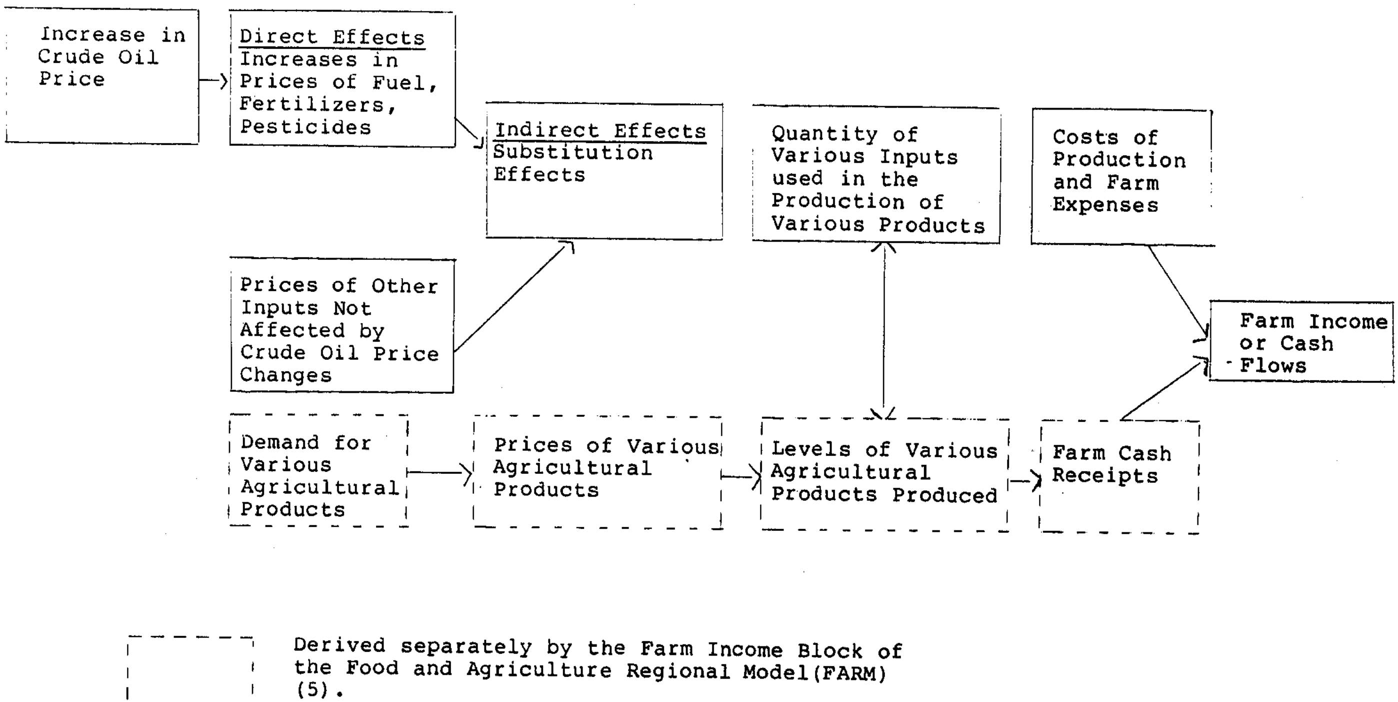
Figure 1: An Overview of the Structure of the Model



determining the net income arising from agricultural production in Canada. Production or supply conditions are reflected by the costs of inputs and prices received for various agricultural products. The prices of different inputs, in turn, determine in part, the quantity of input items being used in production. The parameter estimates are based on the interdependent system consistent with the general equilibrium theory. These features of the model are necessary for impact analysis associated with input price changes.

The structure of the model is outlined in Figure 1. Briefly, the model consists of two components - the farm cash receipt and the farm expense submodels. The farm cash receipts submodel, represented in the lower portion of Figure 1, employs the Farm Income Block of the Food and Agriculture Regional Model (FARM) developed by Tung et. al [5]. In the model farm cash receipts are determined by equilibrium supply/demand conditions of outputs and prices for agricultural commodities. These commodity prices are generated by the Commodity Submodels in FARM for 90 percent of the commodities and are determined exogenously for the remaining ten percent.

The Farm Expense Submodel as developed specifically for this analysis, determines total farm operating expenses in three steps; first, the quantity demanded of each of six factor inputs (energy, energy-based, labour, capital, land and other intermediate inputs) is derived using non-linear equations emphasizing on factor substitution, scale effects and technological changes; second, these major demand categories are converted into costs; third, these derived production costs are transformed into items of farm expenses consistent with National Income accounts employing a set of linear linkage equations. The realized net farm income is then determined as the difference between total cash receipts and total farm expenses. Full details of the farm expenses sub-model are as follows.

Following Lopez and Tung [3], a variant of the generalized Leontief Cost function in its stochastic estimating form is used to estimate the demand for six factor inputs[1].

$$(1)\quad \frac{Xi}{Q} = \sum_j b_{ij} (P_j/P_i)^{1/2} + \alpha_i Q + r_i T + u_i; \; i,j = 1, \ldots 6$$

Where: X_1 = quantity of factor input i ;

P_{ij} = weighted price indexes of the six factor inputs:

Q = the level of output weighted by the 1971 price weights; and

T = time trends representing technological change.

The costs of production (C_i) for these six factor inputs are determined by:

$$C_i = X_i * p_i; \; i = 1 \text{ to } 6$$

These estimates of C_i and lagged dependent variables or time variable are linearly related to the corresponding farm expense items[2] for estimating the

[1] Detailed derivation of these stochastic equations can be found in Lopez and Tung, (3).

[2] Only relevant C_i are employed in the respective equations. For example, fuel expense equation uses energy cost (C_E) and fertilizer expense uses energy-based cost (C_N).

equations employed to derive the detailed farm expenses, subject to the goodness of fit criteria.

Impact Determination

An increase in crude oil prices is expected to have direct effect on increasing the prices of fuel (energy) and of energy-based inputs (fertilizer and agricultural chemicals) which in turn will have short and long-run effects on farm income. The difference between short and long-run effects arises from the possibility of substituting energy and energy-based for non-energy inputs in the long-run.

In the short run, when the prices of energy and energy-based inputs increase due to a crude oil price increase, the possibility of substituting relatively cheaper inputs for energy and energy-based inputs in farm production is limited. Thus, the short-run impact on farm income is the absorption of the full increase in farm expenditures for fuel, fertilizer and agricultural chemicals attributable to the increased crude oil price. It is assumed that the crude oil price increase has no effect on increasing other farm input prices. Given this assumption the short-run income impact depends on the importance of energy and energy related expenses in the farm budget.

In the long-run, as energy and energy-based input prices increase there are possibilities for farmers to substitute other relatively cheaper inputs for energy and energy-based inputs. The long-run impact is, therefore, determined by the elasticities of substitutions among factor inputs.

A number of studies have identified substitutabilities among factor inputs. Berndt and Wood [1] examined substitution possibilities between energy and non-energy inputs in U.S. manufacturing and reported that some limited substitability exists. Griffen and Gregory [2] come to a similar conclusion. Webb and Duncan [6] examined the substitution possibilities for the U.S. agricultural sector and concluded that each pair of inputs among energy, machinery, land, and hired labor are substitutes to some degree; but, substitution between hired labor and machinery holds the greatest potential.

The model, as discussed above is specifically constructed to measure the long-run effects of energy price increases on farm income.

Data Series and Estimation Procedures

Annual data over the 1962-79 period were used for estimating all the equations in the model. For the six factor input demand equations the data required are: price indexes and quantities of the six factor inputs considered and the quantity of output. The Output is represented by the Real Gross Product of agriculture deflated by the aggregate farm product price indexes for each region, 1971 = 100.

Quantities of the six factor input variables considered are the flows of services actually obtained from these factor inputs. It was assumed that inputs related to energy and energy-based groups are utilized within the year. Accordingly, the quantity of energy input was the aggregated expenses for fuel and electricity and the quantity of energy-based inputs was the sum of fertilizer and agricultural chemicals, expressed in 1971 prices. The labor price was the hired labor wage rate and the quantity was hours worked on farms by hired, operator, and family labour. The average hours worked per week by province obtained from Statistics Canada was used to estimate the number of man-hours worked by assuming each worker had worked on average, 40 weeks per year. The hired wage rate was obtained by dividing total wage payments by the estimated hours worked by the hired workers in 1971.

A similar procedure was used to aggregate the different categories of capital flows, which included farm machinery, farm equipment, farm vehicles, farm buildings, and animal stocks. The flows of services from farm machinery, equipment and farm vehicles, were the sum of farm machinery and building depreciation charges, based on 1971 values. The flows of services from animal stocks were assumed to be equal to the sum of average value of different animal stocks expressed in 1971 prices according to their productive lifetime periods. The animal stocks considered were cows, bulls, sows, and sheep; the productive lifetime periods were assumed to be equal to seven years for cows, bulls and sheep and three years for sows.

The flows of services from land were assumed to be identical to the annual rent paid to all land, including owned and rented land, expressed in 1971 prices. The average rent per acre for rented land for each province was used to estimate the rent for owned land.

The quantity of other intermediate inputs was the total expenditures on feed, other livestock, seed, other crops, miscellaneous items, interest payments for farm operating purposes, all expressed in 1971 prices.

The price indexes for the six factor input categories were the weighted price indexes of relevant input components using the 1971 weights.

Two methods were employed to estimate the stochastic equation systems in the model. The six non-linear input demand equations in Generalised Leontief form which required the imposition of symmetry conditions ie. $b_{ij} = b_{ji}$ for $i = J$, the Full Information Maximum Liklihood (FIML) estimation method was used. For this purpose the 1962-79 time series data for the two regions (cross-sections) were combined to obtain 38 observations. The system of six input demand equations which have 38 variables including six dummy variables (one for each equation) was then estimated using FIML.[3] For the 23 linear linkage equations for deriving farm operating and depreciation expenses consistent with National Expenditure Accounts, the ordinary least squares (OLS) method was used.

Estimation Results

The FIML estimation results of the system of six factor input equations are presented in Table 1. The results indicate that the majority of R^2 values fall between 70 to 86 percent except the energy-based input equation showing only 45 percent. However, this should be considered as satisfactory fit, in view of the use of cross-sectional data for the estimation. The signs of the estimated coefficients appear theoretically consistent for all the variables. The "t" ratios for 12 variables including three dummy variables show non-acceptable levels of significance.

The OLS estimates of the 23 linear linkage equations are presented in Tables 2 and 3. The goodness of fit of the equations and the sign consistencies of the coefficients are in general satisfactory, but there are also many non-significant relationships observed. However, the model has been validated for forecasting performance and impact analysis using the root mean square percent error

[3] For FIML estimation the number of data points should be at least equal to or exceed the number of variables.

Table 1: Estimated Parameter Values, Standard Errors, and R^2 for the Six Generalized Leontief Cost Functions.

^{j}component / ^{i}component	Energy	Energy-Based	Labour	Capital	Land	Other Intermediate	Real Gross Output	Time	Dummy+	R^2
Energy	.97715 (5.22)**	-.36931 (-1.699)	.76156 (4.37)**	.13285 (0.98)	.18742 (1.38)	.01019 (0.05)	-.67791 (-7.63)**	-.00167 (0.46)	-.00591 (1.25)	.70766
Energy-Based		-1.18207 (-3.81)**	.52544 (1.42)	.08458 (0.549)	1.42382 (5.62)**	.33783 (1.42)**	.06576 (0.27)	.02684 (2.21)*	.12240 (1.25)	.45426
Labour			-.00096 (-0.004)	.41255 (3.66)**	-1.13384 (-4.22)**	.40032 (2.34)*	-.82373 (3.37)**	.09740 (9.63)**	-.15303 (2.57)*	.74140
Capital				.39540 (4.02)**	.24445 (2.32)*	.39560 (2.83)**	-.79643 (-11.20)**	.01977 (6.41)**	-.02293 (-1.17)	.75100
Land					.87976 (1.85)	.20516 (1.57)	-.58594 (1.57)**	-.01889 (2.20)*	.13127 (2.08)*	.80037
Other Intermediate						-.06930++	-.73237 (8.66)**	.04033 (10.5)**	.0542 (2.54)*	.86267

* Significant at the five percent level.
** Significant at the one percent level.
Note: The values in the parentheses are 't' ratios.
\+ where '0' is for the Eastern region and '1' is for the Western Region. The values for the Western Region intercepts representing the coefficients for own to own price ratio variables, are derived by adding the dummy coefficients to the Eastern region intercepts in the above table.
++ This value is derived as the difference of sum of all the other intercepts from 1.

Table 2: Estimated Parameter Values, Standard Errors, and R^2 for the Linkage Equations, Western Region.+

EXPENSE EQUATIONS	CONSTANT TERM	ENERGY INPUT COST	ENERGY-BASED INPUT COST	LABOUR INPUT COST	CAPITAL COST COST	LAND INPUT COST	OTHER INTERM. INPUT COST	TIME TREND	LAGGED DEPENDENT VARIABLE	R^2
1. FUEL	5.9836 (0.7213)**	0.8767 (0.0060)**						-1.7269 (.1269)**		0.9998
2. ELECTRICITY	-5.2601 (1.1465)**	0.1240 (0.0095)**						1.5834 (.2017)**		0.9917
3. FERTILIZER	17.5581 (7.4081)		0.7180 (.0277)**					0.5409 (.3750)*	-0.1807 (.0893)*	0.9986
4. PESTICIDE	-20.2188 (6.8246)*		0.2735 (.0286)**					-0.5918 (.37718)	0.2156 (.0831)*	0.9938
5. WAGE	-14.4284 (3.5801)**			0.6449 (.0302)**				1.1681 (.5303)*		0.9933
6. FARM MACHINERY	26.4334 (11.7675)*			0.0023 (.0003)**				6.9169 (2.3221)*		0.9637
7. CUSTOM WORK	-33.3199 (30.1052)				-0.0007 (0.0005)			0.7586 (1.1517)	0.8914 (.6692)	0.6006
8. MACHINERY DEPRECIATION	-22.2450 (11.0320)				0.0040 (.0004)**				0.4642 (.1246)**	0.9915
9. INTEREST FOR MACHINERY PURCHASE	-11.9373 (2.4631)**				0.0009 (0.0000)**			-0.6731 (.4860)		0.9785
10. BUILDING REPAIRS	-18.6814 (10.3422)				-0.0004 (0.0002)			0.5899 (.2830)	0.4785 (.2489)	0.9593
11. INSURANCE	-7.5157 (4.3101)				0.0002 (0.0001)*				0.6284 (.2175)*	0.9581
12. FENCING	-13.1360 (2.8942)**				-0.0004 (.00005)**			0.4289 (.2830)	0.4676 (.0928)**	0.9712
13. BUILDING DEPRECIATION	-2.5297 (1.1814)				0.0006 (0.00007)**				0.3434 (.1100)*	0.9944
14. TAX ON BUILDING	12.8983 (.7374)**				0.00008 (.00002)*			0.2403 (.1455)		0.8447
15. FEED	24.8464 (16.2865)				-0.00157** (.0000929)				1.19377** (0.21744)	0.95259
16. OTHER LIVESTOCK EXPENSES	54.8148 (12.2652)				0.0006 (.0003)			0.5818 (.1299)**	0.3136 (.2981)	0.9792
17. RENT	-5.6040 (20.1294)					0.0075 (.0024)*		0.4830 (4.3135)		0.7977
18. TAX ON LAND	22.8778 (2.7529)**					8.05E-07 (3.4E-07)*			1.5468 (0.5782)*	0.9007
19. INTEREST ON LAND PURCHASE	22.6859 (10.9190)					0.0026 (0.0013)			2.5749 (2.3398)	0.7747
20. SEED	2.6776 (1.8134)						0.0010 (8.8E-0.5)**	0.3847 (0.3428)		0.9787
21. OTHER CROP EXPENSES	4.7357 (2.1919)						-6.3E-05 (8.1E-05)	0.1990 (0.0431)**	-0.5233 (0.2345)**	0.8867
22. INTEREST FOR OTHER INTERMEDIATE INPUTS	36.1977 (15.4624)*						0.0102 (0.0019)**	-0.9835 (0.3940)*	-5.4573 (1.4994)**	0.9920
23. MISCELLANEOUS	-2.6558 (3.0647)						0.0015 (4.3E-04)**	0.6386 (0.1588)		0.9891

\+ Values in the brackets are standard errors. *denotes significant at the 5 percent level. ** denotes significant at the one percent level.

Table 3: Estimated Parameter Values, Standard Errors, and R^2 for the Linkage Equations, Eastern Region.+

EXPENSE EQUATIONS	CONSTANT TERM	ENERGY INPUT COST	ENERGY-BASED INPUT COST	LABOUR INPUT COST	CAPITAL COST COST	LAND INPUT COST	OTHER INTERM. INPUT COST	TIME TREND	LAGGED DEPENDENT VARIABLE	R^2
1. FUEL	37.1990 (1.6969)**	0.3709 (0.0261)**						1.1423 (.2821)**		0.9909
2. ELECTRICITY	-30.7208 (1.4703)**	0.5502 (.0226)**						-0.9263 (.2440)**		0.9933
3. FERTILIZER	8.9553 (1.5438)**		0.7623 (.0134)**					-0.7523 (.2942)**		0.9987
4. PESTICIDE	-8.6516 (1.7776)**		0.2368 (.01545)**					0.7165 (.3388)*		0.9874
5. WAGE	-34.7630 (2.6026)**			0.8742 (.0175)**				0.6431 (.4286)		0.9987
6. FARM MACHINERY	25.8842 (2.4710)**				0.0020 (1.2E-4)**			2.5026 (.5054)**		0.9934
7. CUSTOM WORK	26.6087 (1.5161)**				-1.24E-4 (7.1E-5)			2.6782 (.3101)**		0.9397
8. MACHINERY DEPRECIATION	-12.8701 (4.4023)*				0.0018 (5.2E-4)**				0.7457 (.1238)**	0.9943
9. INTEREST FOR MACHINERY PURCHASE	-12.5005 (1.6724)**				0.0012 (7.8E-5)**			-0.6107 (.3421)		0.9817
10. BUILDING REPAIRS	9.81378** (1.45368)				0.0000798** (.0000068)			1.37198** (0.29735)		0.98767
11. INSURANCE	-0.8392 (.5614)				1.3E-4 (4.4E-5)**				0.5205 (.2149)*	0.9613
12. FENCING	-1.0282 (1.1081)				-1.3E-4 (8.7E-5)			0.1043 (.0539)	0.5644 (.2199)	0.9420
13. BUILDING DEPRECIATION	-3.8189 (3.1746)				4.4E-4 (3.1E-4)				0.9342 (.1391)**	0.9926
14. TAX ON BUILDING	10.0634 (4.3612)*				4.6E-5 (2.3E-5)				0.5330 (.2041)*	0.6729
15. FEED	92.4420 (21.4389)**				0.0077 (.0010)**			9.7423 (4.3853)*		0.9674
16. OTHER LIVESTOCK EXPENSES	-56.6829 (10.0363)**				0.0020 (6.4E-4)*			-1.7598 (1.7099)	0.9543 (.2391)*	0.9658
17. RENT	-27.3960 (3.7451)**					0.0216 (.0021)**		-0.5132 (.5242)		0.9709
18. TAX ON LAND	3.4981 (2.5144)					2.0E-6 (5.7E-7)**			0.5591 (.1748)**	0.8881
19. INTEREST ON LAND PURCHASE	-45.4623 (6.4988)**					0.0235 (.0036)**		-0.4583 (.9097)		0.9311
20. SEED	-2.2348 (2.4811)					0.0015 (1.6E-4)**		2.6165 (.5588)**		0.9854
21. OTHER CROP EXPENSES	13.8935 (1.2826)**						8.8E-4 (8.4E-5)**	-1.2706 (.2889)**		0.9427
22. INTEREST FOR OTHER INTERMEDIATE INPUTS	-12.9475 (4.9448)*						0.0450 (3.2E-4)**	-3.5676 (1.1137)**		0.9830
23. MISCELLANEOUS	-0.1102 (3.0430)						0.0018 (5.0E-4)**	0.5698	0.5698 (.1688)**	0.9911

\+ Values in the brackets are standard errors.
* denotes significant at the 5 percent level.
** denotes significant at the one percent level.

(RMSPE), a good indicator of equation performance. The results indicated that the RMSPE is never over 22 percent which shows high validity for these equations.

Impact of National Energy Program (NEP)

Under the recent National Energy Program (NEP), a new energy price schedule will allow the oil prices in Canada to gradually increase to a maximum of 75 percent of the average world price during the 1981-86 period. The effect of this energy price schedule on farm income depends on farmers' ability to adjust the input mix over time. Accordingly two sets of assumptions are employed for impact estimates: the short and the long-run assumptions. In the short-run it is assumed that farmers are unable to make any input mix adjustment. This implies that all input demands are held constant at the estimated 1980 levels of input-output ratios just prior to the establishment of the new price schedule under the National Energy program. In the long-run all inputs are unbounded.

Given that farmers can adjust input mix as price changes, the impact of NEP on farm income is determined by the difference between the simulated results of

Table 4: Simulated Impact of National Energy Program on Realized Net Income, Canada, 1981 and 1982.

	Short-Run		Long-Run	
	1981	1982	1981	1982
A. Realized Net Income (Mill.$)				
1. Statistics Canada Estimates *	4,304	3,409	4,304	3,408
2. Model Results				
1. "Without" NEP	4,373	3,531	4,960	3,998
2. "With" NEP	4,035	3,029	4,631	3,562
B. Impact				
1. Estimates+	338	502	329	436
2. Percentage Difference‡	7.8	14.2	6.6	10.9

* Statistics Canada estimate for 1982 is the forecast made in December 1981 after the NEP is in effect.

\+ Difference between "with" and "without" NEP

‡ Percentage to "without" NEP

"with NEP" and "without NEP". Under the "with NEP" situation, the price schedule for crude oil, natural gas and electricity established under the NEP, forms the basis for deriving the energy and energy-based input price indices. Using the estimated relationship[4] between the rate of price increase of crude oil and natural gas, and the rates of price increases for fuel, fertilizer and chemicals, the input price indices for fuel, fertilizer and chemicals were derived for the 1981 and 1982 periods. The price index for electricity was projected directly as proposed under the NEP. These price indices were then combined to form energy and energy-based price indices using appropriate weights. The price indices for the non-energy inputs were projected on the basis of growth rates during the 1974-1979 period.

For the "without NEP" situation, the crude oil, electricity and natural gas price schedules were projected from the last price increases prior to the inception of the NEP. These projected price indices were then employed to construct energy and energy-based input price indices using appropriate weights as the "with NEP" case. Other input price indices were same as the "with NEP" case.

The simulated impacts under different assumptions are summarized in Table 4. For Canada, in 1982, we find that, after allowing full substitution possibilities, the NEP is estimated to reduce realized net income by $436 million.

To evaluate the reliability of the impact estimates from the model the simulated realized net income is compared with Statistics Canada's estimates. As shown in Table 4, the short-run "without NEP" result is very close to the Statistics Canada's estimate of $4.3 billion for 1981 when the NEP price schedule was only partially in effect. For 1982, the long-run "with NEP" result is closer to the Statistics Canada's

[4] Dr. H.T.M. Colwell, Head, Energy Research Unit, Energy Division, Production Development Policy Directorate, Agriculture Canada, Ottawa, has estimated that for an increase of one dollar per barrel in crude oil price and $0.15 per 000' cu. ft. in natural gas price, the prices of fuel, fertilizer and chemicals will increase by 6.5, 1.5 and 0.9 percent respectively.

estimate. This suggests that farmers tend to gradually adjust their input mix when the economic and technical circumstances provide them with feasible course of action. This also shows that disregarding substitution possibilities tend to overestimate the real long-run impact. Although the model forecasts of realized net farm incomes are overestimated, this should not affect the impact estimates, as the overestimation errors occur in both "with" and "without" NEP situations under short and long-run cases.

Given the above qualifications of the model, we estimate that realized net farm income in Canada would be $436 million or 11 percent more in 1982 if the NEP had not been introduced by the Canadian government (the long-run case). This magnitude of impact, however, could be reduced in the future if substitutions or input mix adjustments continue to take place. The question then is how much substitution between energy and non-energy inputs farmers can make. When substitutions reach the technical limit continued increase in energy price would have an impact on farm incomes similar to the short-run case. This implies that speeding up technological development to enhance substitution possibilities would be an appropriate way of reducing the effect of the NEP on farm income in the long-run.

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