CO_2 Emissions from Central Canadian Agriculture: Meeting Kyoto targets and its implications

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Abstract

Agriculture sectors dependence on fossil fuel use (both direct and indirect) has increased dramatically over the past decades. Productivity increases have been achieved using technological improvements which use considerable amounts of energy inputs. Concerns about global environmental quality resulted in several countries signing the Kyoto protocol, which came into effect internationally, on February 16, 2005. Canada has made a commitment to the international community to stabilize CO_2 emissions at 6 percent below 1990 levels. The target is supposed to be reached by 2008 and maintained through 2012. This paper estimates the CO_2 emissions from input use in Central Canadian agriculture. Using elasticity estimates, the amount of price increase needed to achieve Kyoto targets is estimated. A 6 percent reduction from 1990 levels implies that CO_2 emissions should be stabilized at 1,424,562 tonnes of carbon. The removal of current provincial farm fuel tax exemption programs will lead to a decrease of only 3.36 percent reduction in CO_2 emissions and is estimated to be at 1,726,363 tonnes of carbon. Fuel prices will have to increase almost 85 percent in order to achieve the target reductions under the Kyoto agreement.

Introduction

Interest in energy use in the late 1970s was mainly because of rising energy prices. At present, environmental and price concerns are on the forefront of the debate. Increased crop production in Canada, as in the rest of the developed world, has been achieved through technical change, that is, through the expanded use of increasingly sophisticated inputs, such as farm machinery, fertilizers, herbicides, and irrigation, and through the clearing of new lands, which all involved the use of commercial energy. And, the substitution of capital for labour has increased the reliance of agriculture on non-renewable energy resources. The agriculture sector contributes to increased CO_2 concentrations in the atmosphere through the use of inputs such as fossil fuels, fertilizers, pesticides, and other energy-based inputs. Methane (CH_4) and Nitrous Oxide (N_20) production from agriculture also pose serious threats to our environment, as agriculture accounts for large proportions of CH_4 and N_20 released into our atmosphere. The primary concerns around these two are their high global warming potentials (GWP), which make them more potent than carbon dioxide.

The concentration of CO_2 and other green house gases (GHG) in the atmosphere has been rising from historical levels, primarily due to fossil-fuel burning and land-use changes. Under the Kyoto protocol, which came into effect internationally on February 16, 2005, Canada has made a commitment to the international community to stabilize CO_2 emissions at 6 percent below 1990 levels. Although, voluntary measures should be given priority, yet the option for stabilization may have to involve the use of economic instruments, such as energy taxes, carbon taxes, and the removal or redirection of fuel rebate programs. These measures could be used as tools to change the current incentive structure and, hence, the energy-use patterns.

Any change in taxes or subsidies that targets energy use is expected to alter the consumption patterns via their impact on relative prices. This, in turn, would affect production costs and input allocation decisions in agriculture. The magnitude of these impacts depends upon the substitution possibilities between energy, energy-based, and non-energy inputs that are employed in agricultural production. An analysis of the impacts of price changes on agricultural energy use requires information on substitution possibilities amongst the factors of production, and on own- and cross-price elasticities of demand for each input

Carraro and Siniscalco (1994) have shown that taxation alone would not have a significant impact on CO_2 emissions because of the low elasticities of substitution between energy and other inputs. In Canada, research on substitution of non-energy for energy inputs in agriculture has been rather limited. In 1982, Lopez and Tung estimated the elasticities of substitution between energy and non-energy inputs. Their results, however, are based on aggregate data (1961-79) for the entire country, and have limited use for policy analysis given the diverse nature of production, especially between Central and Western Canada. The regional differences in resource endowments resulted in different directions in technical change. In the Prairies, the direction has been machinery-using, that is, substituting capital for the scarce factor labour, while in Central Canada energy-based inputs such as fertilizers substituted for the scarce factor land (Karagiannis and Furtan 1990). The result has been different factor intensities in agriculture: high direct energy intensity in the Prairies and high indirect energy intensity in Central Canada. Manaloor and Yildirim (1996) estimated the elasticities of substitution and own and cross price elasticities for Central Canadian agriculture[1].

This paper looks at the two possible scenarios for CO_2 reduction. (1) Removal of provincial farm-fuel tax rebate/exemption programs in Central Canadian agriculture. (2) The increase in the price of fossil fuel to achieve the Kyoto targets. Economic costs and benefits are then measured in terms of predicted changes in net farm income and in government revenue.

Energy Use Patterns in Central Canadian Agriculture

Energy use in agriculture can be divided into two categories: direct energy and indirect energy. Direct energy, the energy required to power machinery and to heat buildings, includes refined petroleum products, natural gas, and electricity. Indirect energy is the energy embodied in other factors of production, such as fertilizers,

[1] The paper uses material from an earlier research by Manaloor and Yildirim (1996)

pesticides, and herbicides. In this study, direct energy includes fossil fuels, electricity, and natural gas.

Table 1 shows the percentage share of crop and livestock in total cash receipts. In 2003, 47 percent of total farm cash receipts in Ontario were from crop production, and 53 percent were from the livestock sector. In Quebec, the split between crop and livestock sectors were less equal than in Ontario, with approximately 28 percent of total farm cash receipts coming from crop production, and 72 percent from the livestock sector. The differences in output mix have implications for the types of and the quantities of energy used in production-related activities in each province. For example, diesel and indirect energy use are used more in crop production activities, while electricity and natural gas are used mostly in the livestock sector.

Table 1 Farm Cash Receipts, for 2003 (in '000$)

	Ontario	**Quebec**
Total Crops	3,725,149	1,429,799
% Total (A)	**47%**	**28%**
Total Livestock	4,173,170	3,664,522
% Total (A)	**53%**	**72%**
Total Payments	585,437	875,221
Total Receipts	8,483,756	5,969,542
Total Receipt less Payments (A)	**7,898,319**	**5,094,321**

Source: Statistics Canada, CANSIM II (2005) Table Number 20001

Direct Energy Use

Electricity and petroleum products constitute the bulk of the direct energy use in Central Canadian agriculture. In both provinces electricity use is substantially higher than the refined petroleum use. Conversions from energy quantities to standard energy measures were made based on the following assumptions: the energy content of all refined petroleum products is 38,680 KJ per litre, natural gas contains 38,020 KJ per m^3, and electricity contains 3.6 TeraJoules per GWh (Statistics Canada, *Energy Statistics Handbook, 1994*). The shares of different types of energy used in Ontario and Quebec for the 2000-03 period are shown in Figures 1 and 2 respectively

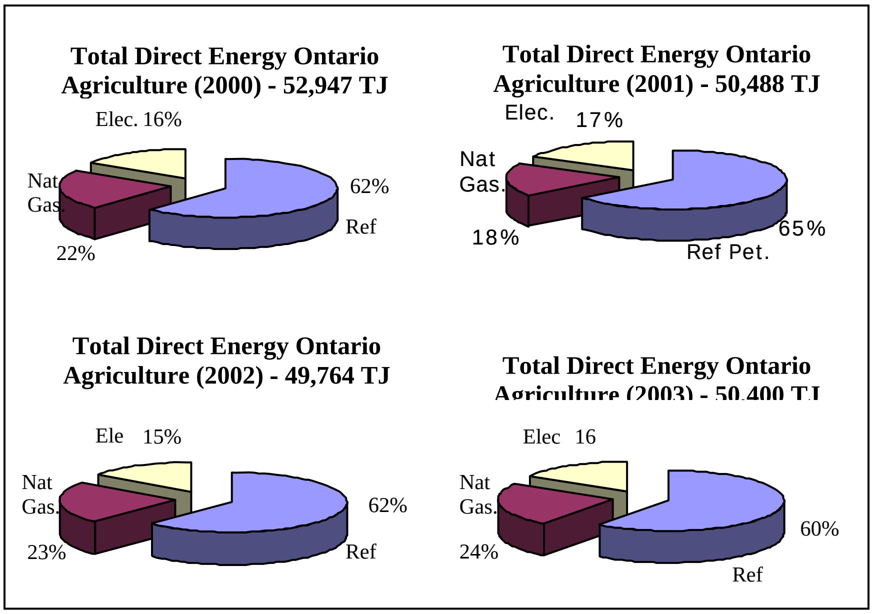

Figure 1 Percentage share of Refined Petroleum, Natural Gas, and Electricity in Ontario Agriculture, 2000-03

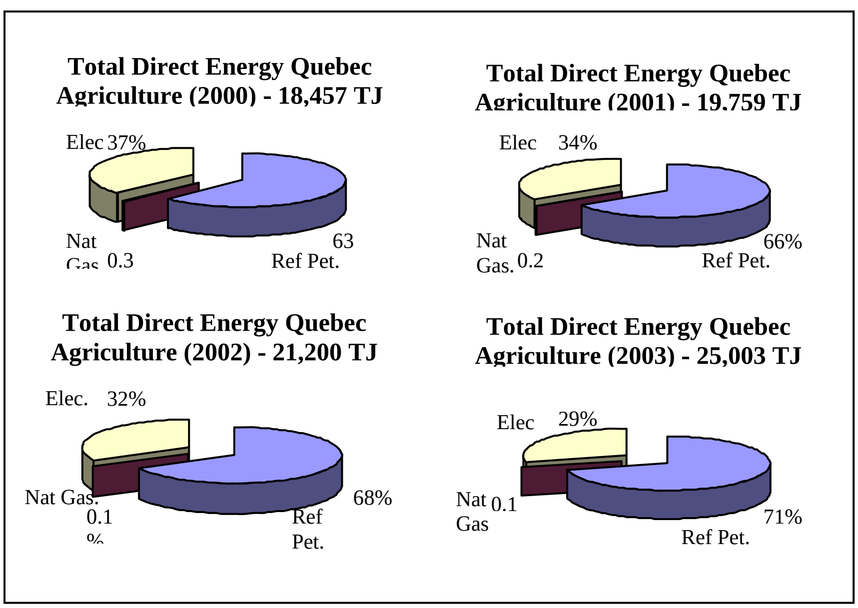

Figure 2 Percentage share of Refined Petroleum, Natural Gas, and Electricity in Quebec Agriculture, 2000-03

Carbon Emissions from Direct Energy and Indirect Energy Use in Agriculture

The calculation of carbon emission from direct energy use in agriculture has to take into account two aspects. First, burning fossil fuels and natural gas releases CO_2 directly into the atmosphere. Second, an input like electricity does not release CO_2 when it is used, but the inputs that are used to generate electrical energy release CO_2. Therefore, to calculate carbon emissions, the energy content of inputs must be broken down by the percentage of energy types embodied in each specific input. It is estimated that carbon emissions released into the atmosphere from burning liquid fuels, natural gas, and coal are 22.29 kg C per GJ, 13.78 kg C per GJ, and 24.65 kg C per GJ, respectively (Marland 1990). These were used as conversion factors to calculate total emissions in Central Canadian agriculture.

Indirect energy refers to the energy content of farm inputs, such as fertilizers, herbicides, farm buildings, and machinery. It is estimated that indirect energy accounts for approximately 60 percent of the total energy used in agricultural production in North America (Fluck 1992). In this report, the term "indirect energy" is used narrowly to include only fertilizers and farm chemicals. There are two reasons for this: first, estimating the energy content of farm machinery and buildings is too complicated, and second, the energy content of these inputs, like sunk costs, does not vary with the farm production decisions. The energy content of these inputs varies by the type of fertilizers and herbicides. The energy invested in producing, storing, and transporting fertilizers is assumed to be 60,700 KJ per kilogram of nitrogen, 12,560 KJ per kilogram of phosphate, and 6,700 KJ per kilogram of potash. The breakdown of energy in nitrogen fertilizer is 90 percent natural gas, 5.2 percent liquid fuels, and 4.8 percent electricity. The energy embodied in phosphate is 47.4 percent electricity, 26.7 percent liquid fuel, and 25.9 percent natural gas. Potash contains 42.1 percent electricity, 31.3 percent liquid fuel, and 26.7 percent natural gas (Pimentel 1980; and Lockeretz 1980).

Fertilizers, herbicides, and pesticides are used primarily for agricultural purposes. Like electrical energy, the use of these inputs does not release carbon directly but the inputs embodied in the manufacturing process contribute to CO_2 emissions. Nitrogen is the dominant source of CO_2 emissions among the three fertilizers, with almost 90 percent of the total fertilizer energy derived from nitrogen and 90 percent of the total CO_2 from fertilizer use associated with nitrogenous fertilizers.

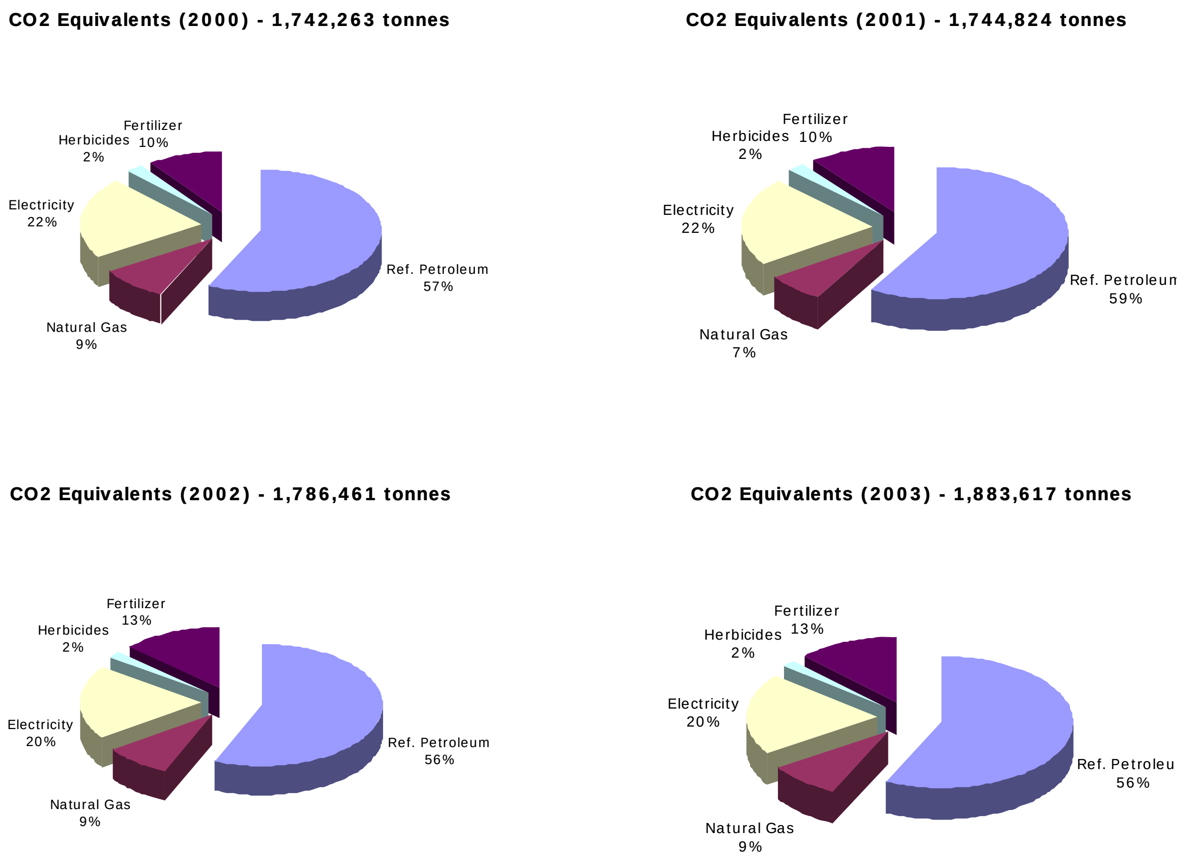

Figure 3 Total CO_2 emissions from different energy inputs used in Central Canadian agriculture, 2000 – 2003

Figure 3 shows the shares of CO_2 emissions from different energy sources for the period 2000 to 2003. The contribution of refined petroleum products to the total CO_2 emission in agriculture was around 56 percent. Fertilizer use accounted for approximately 13 percent of the total carbon emissions from agriculture in 2003.

EMPIRICAL ANALYSIS

Conceptual Model

Agricultural production is characterized by a synergistic nature of multiple inputs to produce a given level of production (often joint outputs). To capture the characteristics of input demands, and to estimate the responsiveness of input allocation to changes in relative prices, a system of demand equations, derived from a dual cost function, were specified for estimation. In this analysis, the following Translog Cost Function was utilized for empirical estimations:

$$\ln C(w,q) = a_o + a_q \ln q + \Sigma_j a_j \ln w_j + (1/2)\, \Sigma_j \Sigma_k b_{jk} \ln w_j . \ln w_k + \Sigma_j b_{jq} \ln w_j . \ln q + \Sigma_j b_{jt} \ln w_j \ln t.$$

Then, applying Shepard's Lemma the following input share equation can be obtained:

$$\delta \ln C / \delta \ln w_j = (\delta C/C)/(\delta w_j/w_j) = (\delta C/\delta w_j).(w_j/C) = (X_j w_j)/C = S_j.$$

Hence,

$$S_j = a_j + \Sigma_k b_{kj} . \ln w_k + b_{jq} \ln q + b_{jt} \ln t, \text{ for } j = 1, 2, \ldots, n$$

Regularity conditions in this case translate into the following: homogeneity of degree one in prices implies that $\Sigma_j a_j = 1$, $\Sigma_j b_{jk} = 0$, and $\Sigma_k b_{jk} = 0$. The equality of second order cross-derivatives implies the symmetry constraint, $b_{jk} = b_{kj}$, and concavity implies that the matrix of second derivatives of the cost function with respect to input prices or the matrix of partial elasticities of substitution is negative semi-definite.

Data and Variables

Expenditures on inputs were grouped into six categories: direct energy, indirect energy, machinery, labour, land and buildings, and miscellaneous inputs. The direct energy category includes the farm business portion of electricity and fuel expenditures. The indirect energy includes expenditures on fertilizers and herbicides. Expenditures on machinery repair and depreciation were used to reflect expenditures on machinery services. Similarly, depreciation on buildings, cash and share rent, property taxes, and repairs to buildings and fences were used to represent annual expenditures on the services of land and buildings. Labour expenditures include the wages of the farm operator and family labour, and wages paid to hired labour. Data on wages and the number of hours worked by the three categories of labour were obtained from the Policy Branch of Agriculture and Agri-Food Canada. The miscellaneous inputs category includes expenditures on seed, irrigation, twine, wire and containers, custom work, and other livestock expenses.

Method of Estimation and Results

Manaloor and Yildirim (1996) estimated own and cross-price elasticites for energy inputs. It has been assumed that the elasticity estimates have not changed drastically and have been use din the present study. Table 4 shows the short-run estimates of own- and cross-price elasticities of demand for inputs employed in Central Canadian agriculture. The estimated own-price elasticities for inputs, reported as the diagonal elements of Table 4, have negative signs, as expected. The magnitude of each of these elasticities is less than one. This implies that the demand for inputs are price inelastic.

Among the six input categories considered in this study, direct energy is least responsive to changes in its own price. This has implications on policy formulation for reductions in CO_2 emissions, i.e., given the production technology, an increase in the price of direct energy inputs will not lead to large reductions in demand for these inputs, and hence, in CO_2 emissions in the short run.

Table 4 Estimated Own- and Cross-Price Elasticities of Input Demands

	Prices of					
Quantity	Labour	Direct Energy	Indirect Energy	Machinery	Land & Bldgs	Miscellaneous Inputs
Labour	-0.4494	0.0276	0.0094	0.1291	0.1424	0.1410
Direct Energy	0.2026	-0.2152	-0.1394	0.0423	-0.0197	0.1294
Indirect Energy	0.0660	-0.1336	-0.3103	0.2104	0.0436	0.1240
Machinery	0.5037	0.0225	0.1166	-0.6447	-0.0080	0.0101
Land & Bldgs	0.5184	-0.0135	0.0312	-0.0104	-0.6903	-0.0355
Miscellaneous Inputs	0.2194	0.0274	0.0274	0.0040	-0.0109	-0.2672

Source: Estimated. Manaloor and Yildirim (1996)

The responsiveness of indirect energy inputs to changes in its own price is also small. This result is different from those obtained by the authors for prairie agriculture, where the demand for this input was elastic. In Central Canada, the summer fallow acres are negligible compared to total cultivated acres, thus a switch between mechanical weed control and chemical control is not a common practice.

The estimated cross-price elasticity of each input demand category with respect to direct energy and indirect energy price is small, indicating that a change in the direct energy or indirect energy price would have very little impact on the demand for other inputs. The cross price elasticities of demand for direct and indirect energy with respect to other input prices are also small. This indicates that changes in quantity of energy inputs will be small in response to changes in other input prices.

Impact of the Removal of provincial farm fuel rebate

Removal or redirection of subsidy/tax can be used as a measure to reduce carbon/GHG emissions. Fuel used for agricultural practices in Quebec and Ontario is eligible for tax rebate. Table 5 shows the fuel tax rebates and average gasoline and diesel prices paid by Ontario and Quebec farmers in 2002.

Table 5 Provincial Farm Fuel Prices and Tax Rebates in 2002 (cents/litre)

	Prices		Fuel Tax Rebates	
	Gasoline	Diesel	Gasoline	Diesel
Quebec	67.68	64.33	15.2	15.2
Ontario	63.65	58.04	14.7	14.7
Central Canadian Average (weighted)[2]	**64.40**	**60.64**	**14.82**	**14.90**

The short-run impact of the removal of provincial farm-fuel tax rebates is estimated and its impacts on CO_2 emissions, farm income, and government revenue were analyzed. For the year 2002, the removal of tax rebates on farm-fuel use is equivalent to a 23.02 and 24.58 percent increase in the average gasoline and diesel prices. This is approximately a 23.75 percent increase in the average machinery fuel (gasoline + diesel) price paid by farmers in Central Canada. Thus, the increase in direct energy price would result in the demand for all factors of production to change through the substitution

[2] Weights used are the quantities of gasoline and diesel.

effects. The changes in CO_2 emissions, however, result from changes in the use of direct and indirect energy inputs only.

The magnitude of these changes is determined by the own-price elasticity of demand for direct energy input (-0.2152), and by the cross-price elasticity of demand for indirect energy input with respect to energy price (-0.1336) (see Table 4). The changes in direct and indirect energy use and CO_2 emissions calculated using these elasticities indicate that a 23.75 percent rise in direct energy price would reduce energy use, and CO_2 emissions, by 3.40 percent. Because direct and indirect energy are complements, the use of indirect energy declines resulting in the reduction of emissions by 3.17 percent. The cumulative effect of the direct and indirect energy changes is a 3.36 percent reduction in CO_2 emissions. These effects are summarized in Table 6. The above calculations did not take into account inter-fuel substitution possibilities which are likely to be negligible, at least in the short run.

Table 6. Impact of the Removal of Farm Fuel Tax Rebate on CO_2 Emission (tonnes of C)

	With Tax Rebates (2002)	**Without Tax Rebates**
Direct Energy		
Refined Petroleum	1,009,692	958,087
Electricity	351,977	351,977
Natural Gas	156,913	156,913
Total Tonnes C	1,518,583	1,466,977
% change		**-3.40**
Indirect Energy		
Fertilizer	237,301	229,771
Herbicides	30,577	29,607
Total Tonnes C	267,878	259,379
% change		**-3.17**
GRAND TOTAL	1,786,461	1,726,356
% change		**-3.36**

Source: Estimated.

Another important aspect of the removal of provincial farm fuel tax rebate programs is its potential impact on farm expenditures and income. These changes result from changes in the quantity of fuel and other inputs used in the production process, and changes in farm fuel prices. As a result of the calculated 23.75 percent increase in farm fuel prices, the cost of producing the same level of output increases. The demand for inputs that are substitutes for direct energy input, namely, indirect energy, machinery, and land and buildings, would increase, and the demand for complementary inputs, namely, labour and miscellaneous inputs, would decrease. Keeping the level of output and output prices constant, the increased costs translates into an equal amount of decline in net cash income. Consequently, net cash income from Central Canadian agriculture is estimated to decrease by 8.60 percent.

Table 7 Economic Effects of the Removal of Provincial Farm Fuel Rebates (`000 $)

	2002[1] Farm Income	After the Removal of Tax Rebates				
		Farm Income	Change in Farm Income	% Change in Farm Income	Change in Tax Revenue	Net Welfare Gains
Quebec	1,008,561	944,829	-63,732	-6.32	+42,886	-20,845
Ontario	1,172,355	1,048,581	-123,774	-10.56	+64,934	-58,840
TOTAL	2,180,916	1,993,410	-187,506	-8.60	+107,820	-79,685

Source: Estimated.
Note: [1] Statistics Canada, CANSIM.

The removal of provincial tax rebate program would result in a different rate of change in net income in each province because of the differences in input use across the provinces. The values reported in the "Change in Tax Revenue" column of Table 15 are estimates of the cost of these programs to provinces, which would have been collected as tax revenue if there were no farm fuel tax rebate programs. In each province, the estimated change in tax revenues exceeds the predicted decline in farm income, indicating net welfare gains from the policy change.

Summary

In summary, the removal of provincial farm fuel tax exemption would (i) reduce CO_2 emissions by 3.36 percent from 2002 levels and result in net welfare gains. In other words, provincial governments could compensate farmers, in a non-distorting way, for the losses in farm income and society overall would still be better off.

To achieve a 6 percent reduction from 1990 levels, as outlined in the Kyoto protocol, CO_2 emissions should be stabilized at 1,424,562 tonnes of carbon. The removal of current provincial farm fuel-tax rebate program will lead to a decrease of only 3.36 percent reduction in CO_2 emissions and is estimated to be at 1,726,363 tonnes of carbon. Fuel prices will have to increase almost 85 percent in order to achieve the target reductions under the Kyoto agreement.

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