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ASSESSING THE IMPACT OF A CARBON TAX ON THE ALBERTA ECONOMY

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INTRODUCTION

The international community has become increasingly concerned about the impact of global warming on the world economy. Rising concentrations of so-called greenhouse gases such as carbon dioxide, chloroflurocarbons, methane and nitrous oxide have been linked to an increase in the earth's average temperature. These gases have the property of being transparent to incoming solar radiation but of absorbing infrared radiation with wavelengths at which the earth emits half of its heat. The absorbed heat is reradiated downward and is effectively trapped near the surface. This phenomenon has become known as the "greenhouse effect" (Nordhaus, 1993, 12).

Estimates of the potential economic impact of global warming on the global economy vary significantly and depend on the magnitude of global warming assumed and on the assumptions of the modelling exercise regarding how economic activity responds to a rise in the earth's temperature (Nordhaus, 1993, 16). However, the correlation between greenhouse gas emissions and global warming has led governments to focus on ways of reducing or stabilizing greenhouse gas emissions as a means of lowering the extent of global warming. Since carbon dioxide accounts for approximately 55 percent of the greenhouse effect, efforts at controlling carbon dioxide emissions have received the most attention(Harrison et al, 1991, 138).

In May of 1990, Canada along with 33 other countries attending the United Nations Economic Commission for Europe Conference agreed to stabilize net carbon dioxide and other greenhouse gas emissions at their 1990 levels by the year 2000. The Green Plan released by the federal government in December, of 1990 also adopted

the target of achieving 1990 levels of greenhouse gas emissions in the year 2000 (Rheaume, 1993, 4). Since Carbon dioxide emissions are forecast to be about 15 percent higher in the year 2000 than in 1990 (Harrison et al, 1991, 1). Consequently the federal government will have to bring forward policies that either cut domestic greenhouse gas emissions or bring about equivalent emission offsets in other countries if the target is to be achieved.

This paper does not look at the entire array of policy options open to the federal government to stabilize carbon dioxide emissions at their 1990 levels by the year 2000. Instead, our focus is narrow. We assess the impact on the Alberta economy of the federal government adopting a "carbon tax" whose goal would be the reduction of carbon dioxide emissions through increasing the price of fossil fuels. A carbon tax is simply an excise tax on the producers of fossil fuels based on their carbon content.

We focus on a carbon tax not because it is the least cost means of stabilizing carbon dioxide emissions. Indeed, it may be inferior in terms of its economic consequences to other approaches such as employing tradable permits setting carbon dioxide emission levels or offsetting Canadian carbon dioxide emissions through reductions of such emissions in other countries (Rheaume, 1993, 8-11). Our choice of modelling the impact of a carbon tax on Alberta was driven by three considerations:

(1). To highlight the continuing importance of the energy industry to Alberta and the severe economic consequences to the provincial economy that would follow were a carbon tax to imposed.

(2). To demonstrate that the potential impact of a carbon tax on any economy but especially Alberta's is very sensitive to assumptions regarding the distribution of carbon tax revenue, the degree of wage flexibility and the ease of substitution among various energy sources.

(3). To recognize that using a criterion of minimizing administrative costs a carbon tax levied at the well-head would likely be the lowest cost tax option options because the fossil fuel industry is relatively concentrated in terms of both region and numbers of producers. In contrast, an alternative of imposing a tax on all individual sources of carbon emissions would be prohibitively costly in implementation, monitoring and enforcement.

CANADA AND ALBERTA: GREENHOUSE GAS EMISSIONS

Carbon dioxide accounts for approximately 55 percent of greenhouse gases, CFCs, 24 percent, methane, 15 percent and nitrous oxides, 6 percent. Fossil fuels are the source for approximately 80 percent of carbon dioxide emissions (Harrison et al, 1991, 138). It is the large contribution of fossil fuels to the level of green-house gas emissions which accounts for the focus of government policy discussions on the energy industry when options concerning global warming are assessed.

Canada accounts for about 2 percent of total carbon dioxide emissions and ranks 9th in the global context On a per capita basis, Canada ranks fourth in carbon dioxide emissions and Alberta has a level of carbon dioxide emissions which is twice the national average (Harrison et al, 1991, 139-141). Alberta's share of Canadian carbon dioxide emissions is 23.1 percent. while Ontario's share is 30.5 percent, the largest of any province.

Alberta accounts for approximately 80 percent of Canada's gas production, 40 percent of its coal, and 80 percent of its crude oil production (Harrison al, 1991, 1). This concentration of fossil fuel production in the province is why Alberta accounts for a significant share of Canada's greenhouse gas emissions.

Chart 1 shows the shares of carbon dioxide emissions by sector for Canada and Alberta in 1988. The source of emissions in Alberta differs significantly from the national pattern. Conversion losses (when one form of energy is converted into another) accounts for more than 40 percent of Alberta's emissions and less than 20 percent for Canada. Chart 2 shows the sources of carbon dioxide emissions by fuel type for Canada and Alberta in 1988. Natural gas accounts for 26 percent of Canadian carbon dioxide emissions but more than 46 percent of those in Alberta.

Chart 1: Shares of 1988 CO_2 Emissions by Sector for Canada and Alberta

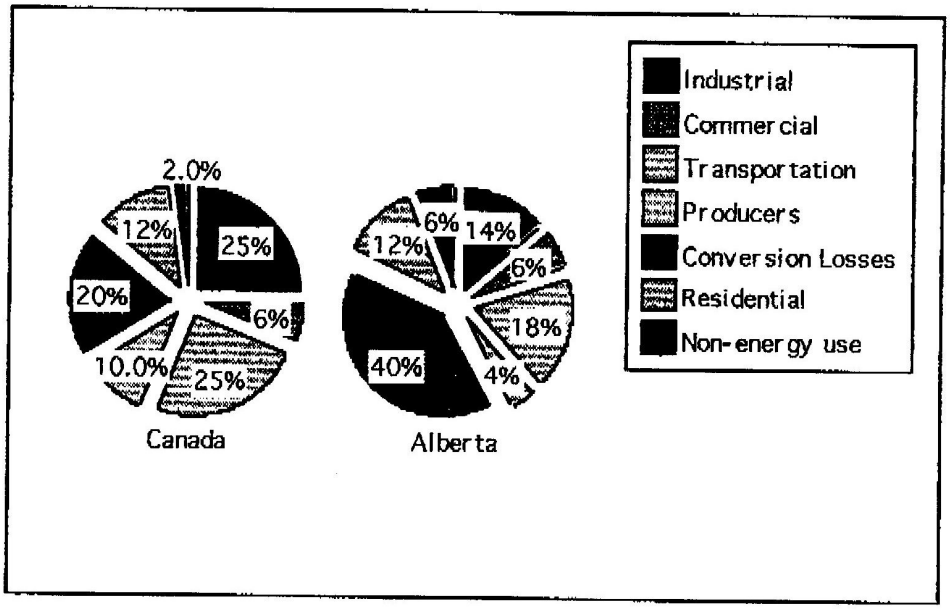
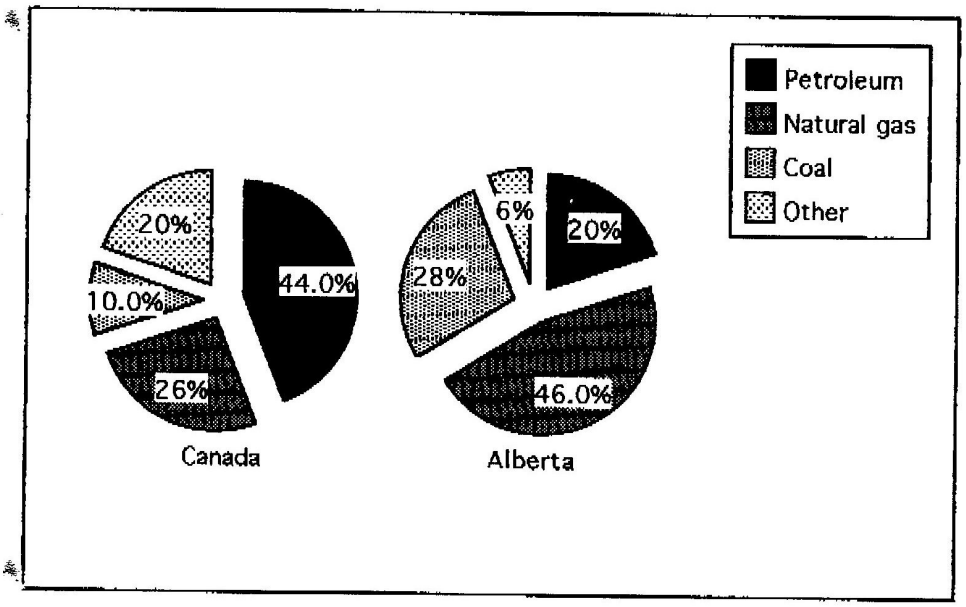


Chart 2: Shares of 1988 CO_2 Emissions by Fuel Type for Canada and Alberta



Source for Charts 1 and 2: D. Harrison and A. L. Nichols (1991), "Market Based Approaches to Managing Air Emissions in Alberta", Discussion Paper Prepared for Alberta Energy, Alberta Environment and the Canadian Petroleum Association.

Table 1
Fossil Fuel Tax Rates
(1990 Dollars per Gigajoule)

Carbon Tax = $150 (1990$ /tonne	Carbon Content (tonnes/GJ)	Tax Rate (1990$/GJ)	Industrial Prices % Change in 2000
Natural Gas	.0153	$2.20	60%
Oil	.0200	$3.00	70%
Coal	.0257	$3.86	130%

Source: "Canadian Competitiveness and the Control of Greenhouse Gas Emissions Through Imposition of a Carbon Tax," June 1993, p. 1 DRI Canada and Marbek Resource Consultants

CARBON CONTENT OF FOSSIL FUELS

Fossil fuels differ in their carbon content as Table 1 indicates. Natural gas has the lowest carbon content (tonnes per gigajoule), followed by oil and coal. These differences in carbon content mean that a given carbon tax will translate into different carbon tax levels depending on the fuel in question. Again, Table 1 from the DRI Canada et al (1993) study indicates that coal prices would increase 130 percent, oil prices 70 percent and natural gas prices 60 percent in the case of a carbon tax of $150 per tonne of carbon. This tax achieves a stabilization of greenhouse gases at their 1990 level by the year 2000 in Canada through a reduction in consumption of fossil fuels.

THE ECONOMIC IMPORTANCE OF THE ENERGY SECTOR IN ALBERTA

The energy sector remains the economic mainstay of the Alberta economy. The oil, gas and minerals sectors accounted for 14.8 percent of Alberta's gross domestic product at factor cost and employed 5.8 percent of all Alberta workers in 1992. Natural resource royalties accounted for a further 3.0 percent of gross domestic product in that year. Investment in the energy sector accounted for 19.1 percent of Alberta's total investment in 1992 (Alberta, 1993, 12). The provincial budget for 1994-95 estimates that natural resource royalties will account for 19.6 percent of provincial government revenues (Alberta, 1994, 45). For the calendar years 1992 and 1993 energy exports to foreign markets accounted for approximately 66 percent of total exports.

MODELLING THE APPLICATION OF A CARBON TAX

In this study we assume that the federal government structures a carbon tax in such a way that domestic consumers bear its brunt while fossil fuel and petrochemical exports are exempt. Thus the competitive position of Canadian fossil fuel and petrochemical producers in international markets is, at least in theory, unaffected. Since we treat oil, natural gas and coal producers as price-takers in international markets, the imposition of the carbon tax does not affect well-head or producer prices directly. Instead, domestic intermediate and final demand prices rise by the extent of the carbon tax imposed on the particular fossil fuel. The rise in domestic

fossil fuel prices will lead to a decline in the quantity of fossil fuels demanded for intermediate and final demand uses and a corresponding decline in carbon dioxide emissions.

A carbon tax based on carbon content of fossil fuels will mean that coal prices increase by far the most, followed by oil and natural gas prices (Table 1). Purchasers of fossil fuels are likely to be responsive to changes in their relative prices. Hence the results of the modelling exercise must be sensitive to the likely substitution of cheaper for more expensive fuels inclusive of the carbon tax to be assessed. The greater the ease of substitution, for example, the smaller the negative impact of a carbon tax on domestic purchasers of coal.

Another critical issue in modelling a carbon tax is who gets the tax revenue. A carbon tax of $150 per tonne would generate $17.5 billion (1990 $) annually in the year 2000 (DRI Canada et al, 1993, p. 13). On can think of a variety of criteria on which to base the allocation of the monies between the federal and provincial governments. We assess two in this study. Under the first criterion - "low remittance" - the province gets a share of the revenues equal to its population share. In Alberta's case in 1994 this would be 9.4 percent. The second criterion - "full remittance" - would see Alberta receive tax revenues equivalent to its share of the national value of fossil fuel production of approximately 85 percent.

A final consideration in assessing the impact of a carbon tax on the Alberta economy is how the labour market adjusts to economic shocks. A key factor is the degree of wage flexibility. In an economy where wages can rise and fall in the short-term, a negative shock such as the imposition of a carbon tax, would see pressure on wages to fall. As wages fell, labour laid off from the energy sector and other hard hit industries would be hired in other export sectors. The decline in wages would be the means by which labour was shifted from declining to expanding industries. The extent of the negative effect of the decline in fossil fuel employment would be offset somewhat by an expansion of employment elsewhere in the economy. On the other hand, if wages are inflexible then a contraction of employment in the energy industry would result mainly in higher unemployment rather than a reallocation of employment.

MODELLING THE ALBERTA ECONOMY

In the model of the Alberta economy used in the study there are fourteen producing sectors: crude oil, natural gas, coal, electricity, agriculture, forestry, food and beverages, import-competing manufacturing, forest products, other non-metallic minerals, petrochemicals, construction, services, and government. The energy sectors are treated as price-takers as are the agricultural, food and beverage, import-competing manufacturing, and petrochemical sectors. We treat prices of the remaining sectors as being determined within the provincial economy.

We've structured the model to ask a very specific question: "what is the impact of a carbon tax on the economic well-being of *current* residents of Alberta?" The labour force is assumed fixed to the province but mobile among sectors and the capital stock is assumed fixed at the sectoral level. Interprovincial migration and adjustments to the capital stock in response to the effects of a carbon tax are not permitted. These longer run adjustments of population and investment obscure the immediate impact of a carbon tax on the economic well-being of Albertans resident in the province at the time such a tax is imposed. This specification permits one to assess the regional burden of a particular policy initiative (Norrie and Percy, 1983, 329)

The model is described in greater detail in Percy (1994) and Ogus (1994). There are five basic blocks of equations in the model. The first links the determination of producer prices to input prices and technological change. For analytical convenience production is assumed to exhibit constant returns to scale. While primary inputs of capital, labour and land can be substituted for one another, intermediate inputs are used in fixed proportions. However, energy inputs of oil, natural gas, and coal can be substituted for one another in a constant elasticity of substitution specification.

The second block of equations links producer prices to demand prices. Demand prices exceed (are lower than) producer prices depending on

the value of indirect taxes (subsidies) and transportation costs. Producer prices of oil, natural gas and coal are beyond Alberta's influence and set in the world market. Thus, we have ignored the potential market power of Alberta in natural gas.

The third block of equations links the demand for primary inputs of labour and capital to supplies of these factors. The demands for labour and capital are modelled as derived from the underlying production technology specified in the first block of equations. The supplies of land and capital to the Alberta economy are taken as fixed. In the case of labour, two specifications of the labour market are assessed. One assumes full employment and complete wage flexibility while the other treats wages as highly inflexible leaving unemployment as the mechanism of adjustment to shocks affecting the labour market.

The fourth block consists of equations in which the components of aggregate demand (consumption, intermediate demands and net exports) equal aggregate supply.

The fifth block of equations links demand prices of goods entering interregional and international trade to prices in the international economy. In the cases of oil, natural gas and coal the link is in terms of domestic producer prices to international prices. Finally, there are equations specifying the determinations of aggregate gross domestic product, the gross domestic deflator and consumer price index.

There is no requirement in the model that the change in exports must equal the change in imports, or that the change in savings must equal the change in imports. Since the model is short-run in nature and the capital stock is fixed there is no change in investment. Consequently we have assumed no savings function. The exchange rate is assumed fixed and the balance of payments passively accommodates any change in the trade balance. The modelling exercise ignores any adjustments of national macroeconomic variables such as exchange and interest rates in response in response to a carbon tax.

Many of the underlying economic relationships of the model are nonlinear. For computational ease the model is transformed into a linear system by converting each of the equations from a relationship in terms of levels of variables to one of proportional or percentage change. The model simulation is a comparative static exercise which calculates the changes required to achieve new activity levels in response to the imposition of the carbon tax. Thus the results indicate the particular impact of the policy in question as all other exogenous variables such as productivity growth, investment and rest of world price changes are assumed unchanged. Models of this structure have been used extensively, for example, to assess policy scenarios in Australia (Dixon et al, 1982).

SIMULATION RESULTS OF A CARBON TAX

Tables 2 and 3 provide results for economy-wide variables of the imposition of a carbon tax which leads to an increase in domestic demand prices for oil of 10 percent, natural gas of 6.98 percent and of coal of 19.81 percent under a variety of assumptions. Table 2 shows the percent change in the economy wide variable as a result of the imposition of a carbon tax at these rates. The least damage occurs (Table 2, column 2) when the following conditions prevail:

- wages are assumed highly flexible;
- there is a high degree of substitutability among fossil fuels; and
- the province receives full remittance of carbon tax revenues.

Table 2
Impact on Alberta Economy-wide Variables of a Carbon Tax with Full Remittance to the Province
(% Change in Variables)

	Wage flexibility No substitutability	Wage flexibility High substitutability	Low wage flexibility No substitutability	Low wage flexibility High Substitutability
Real Gross Provincial Product	-1.17	-1.13	-3.49	-3.42
Employment	0.0	0.0	-6.42	-6.28
Unemployment	0.0	0.0	100.51	98.45
Wages	-4.81	-4.65	-0.06	-0.06
Real Wages	-2.14	-2.07	1.40	1.37

Real gross domestic product falls by only 1.13 percent. Since population is assumed fixed, gross domestic product per capita also falls by 1.13 percent. Real wages fall by 2.07 percent to maintain full employment. A carbon tax in this scenario tends to redistribute real income from labour to capital since the fall in real wages exceeds the fall in aggregate real income.

A carbon tax has the greatest negative effect when

- wages are inflexible;
- energy substitution is low; and
- the province's share of the carbon tax is equal to its share of the Canadian population (Table 3, column 3).

Real gross domestic product (and per capita product) falls by 5.19 percent (by about $5 billion in 1994 dollars) in this scenario. Unemployment increases by 126.3 percent which corresponds to an increase in the unemployment rate from 6 to approximately 13.5 percent, or some 200,000 Albertans. For those Albertans who hold on to their jobs in the inflexible wage scenarios the outcome is positive - real wages increase by 1.93 percent.

Table 3
Impact on Alberta Economy-wide Variables of a Carbon Tax with Low Remittance to the Province
(% Change in Variables)

	Wage flexibility No Substitutability	Wage flexibility High substitutability	Low wage flexibility No Substitutability	Low wage flexibility High substitutability
Real Gross Provincial Product	-2.28	-2.23	-5.19	-5.11
Employment	0.0	0.0	-8.06	-7.92
Unemployment	0.0	0.0	126.34	124.01
Wages	-6.04	-5.86	-0.08	-0.08
Real Wages	-2.51	-2.46	1.93	1.90

In all the inflexible wage scenarios, real wages of those who remain employed increase. This result arises from the fact that nominal wages fall very little but consumer prices fall by a significant amount. Hence the purchasing power of nominal wages increases. However, the large fall in employment and the corresponding rise in unemployment contribute to a large decline in aggregate economic activity and income.

The negative impact of a carbon tax is increased significantly when wages are inflexible. If we examine Table 2 and compare column 2 to column 4, the decline in real aggregate economic activity is three times greater as we move from flexible to inflexible wages.

MOST LIKELY SHORT RUN IMPACT OF A CARBON TAX ON ALBERTA

The obvious question is which among these scenarios depicts the most plausible short-run impact of a carbon tax on the Alberta economy? If our interest is the immediate impact then the inflexible wage and no substitutability scenario (column 3 of Tables 2 and 3) - the "worst-case" - is most likely.

In the medium term, the economy would adjust to the imposition of a carbon tax through interprovincial outmigration, disinvestment and

a shift in industrial structure. The nature of these adjustments is suggested in Table 4 which provides greater detail on industrial structure and rates of return for this worst-case scenario. For example, rising unemployment or falling real wages would lead to outmigration. Negative returns to capital signal subsequent disinvestment while positive rates would induce investment.

Table 4
Impact on Industrial Structure and Exports of Alberta of a Carbon Tax: The Cases of Low Remittance and High Remittance of the Proceeds to Alberta Under Conditions of Low Wage Flexibility and No substitutability
(% Change in the Variables)

	Low Remittance	High Remittance
Value of Production[1]		
Oil	0.21	0.14
Natural Gas	0.21	0.14
Coal	0.24	0.16
Electricity	-3.24	-2.45
Agriculture	0.75	0.54
Food and Beverage	2.66	1.87
Import Competing Manuf.	1.40	0.93
Petrochemicals	-33.87	-35.06
Services	-8.06	-5.95
Real Exports[2]		
Oil	19.20	19.76
Natural Gas	1.53	1.38
Coal	18.16	16.96
Agriculture	0.46	0.42
Food and Beverage	117.97	81.71
Petrochemicals	-66.71	-70.43
Real Imports[3]		
Manufactures	-8.18	-5.76
Return to Capital[4]		
Oil	0.69	0.47
Natural Gas	0.69	0.47
Coal	0.76	0.52
Electricity	-16.51	-15.54
Agriculture	1.54	1.10
Food and Beverage	6.42	4.50
Services	-9.21	-6.83
Petrochemicals	-66.58	-68.90

1. Calculated using producer prices
2. real quantity of exports
3. real quantity of imports
4. nominal rental rate of capital

Some of the results in Table 4 at first glance appear counter-intuitive. The imposition of a carbon tax, for example, leads to both an increase in the production and in the exports of fossil fuels. Two factors account for these results. First, the decline in domestic demand for fossil fuels leads to a redirection of fossil fuels from domestic uses to the export market. Second, the imposition of the carbon tax leads to a fall in service or non-traded goods prices. The fall in these prices further enhances the competitive position of fossil fuel producers.

Traditional export sectors in Table 4 such as agriculture, food and beverages and forest products expand production and exports. The import-competing manufacturing sector expands and imports of manufactured goods fall. The impact on the petrochemical industry is quite devastating with the value of production, the volume of exports and the returns to capital in the industry all falling dramatically. The electricity industry is also hard hit since in Alberta virtually all electricity production is coal fired. The sharp rise in coal prices, almost double the increase in oil prices, reduces the quantity demanded of electricity and significantly depresses the return to capital in the industry.

The sharp fall in returns to capital in the service sector highlights what would happen to residential and commercial property values. Housing prices would inevitably fall as consequence of a carbon tax. The decline in real income and the rise in electricity rates both contribute to the fall in the prices of those goods such as housing whose values are determined solely by domestic demands. Many Albertans would experience a significant fall in home equity. Similarly, financial institutions with portfolios of residential and commercial real estate would find that the collateral value of these assets would fall.

How Realistic Are These Estimates?

Several factors must be borne in mind when assessing these simulation results. First, we have modelled a carbon tax which leads to a 10 percent increase in the price of oil and increases in natural gas and coal prices corresponding to their carbon content. Yet the estimates of Table 1 suggest that it would require fossil fuel prices increases 7 times greater than those we have simulated here to stabilize carbon emissions at their 1990 level in the year 2000.

Moreover we have not taken into account three other important factors likely to exacerbate the negative effect of a carbon tax on the Alberta economy. First, the imposition of a carbon tax would likely induce a permanent decline in investment intentions in the province. The introduction of a carbon tax would clearly invoke memories of the National Energy Program and lead investors to attach greater political risk to investments in Alberta and other fossil energy producing provinces. Any decline in autonomous investment would lead to a decline in aggregate economic activity.

Second, the sharp rise in energy prices that occurred in 1973 was correlated with a significant decline in the rate of total factor productivity growth in industrialized economies. The extent to which the productivity slow down was due to higher energy prices is not clear but some of it was a consequence of firms facing difficulty in adjusting plant and equipment to a regime of higher energy prices. Since total factor productivity growth contributes a large share of overall economic growth, any decline in its growth would reduce aggregate growth in Alberta and the rest of Canada.

Finally, the carbon tax is modelled as a "stand-alone" initiative. The imposition of a Canadian carbon tax is assumed to reduce Canadian demand for fossil fuels but supplies intended for the domestic market are then redirected to the American market. Were the United States to adopt a similar carbon tax then this option for Canadian fossil fuel producers would be even less attractive as American demands for fossil fuels and also of energy imports declined.

One aspect of our modelling exercise likely leads to an over-estimate of the impact of a carbon tax on the Alberta economy. We have treated the price of coal as being set in international markets. Since such a small share of coal production is exported, our assumption that the tax would be shifted forward entirely to the electricity industry and then to consumers may not be realistic. The rise in electricity prices

accounts for some portion of the activity decline in electricity using industries.

The estimates by DRI Canada et al (1993) of the impact on Alberta of a carbon tax (given in Table 1) are -1.9 percent in 1995, -4.0 percent in 2000 and -3.3 percent in 2005 and 2010. The corresponding national estimates are lower (DRI Canada et al, 1993, 23). Unfortunately, the results are not strictly comparable because of differences in modelling techniques. Also the DRI Canada et al study permits a broader array of adjustments at the macro level in response to a carbon tax. Our study, on the other hand, is concerned with the immediate impact on the income and employment of current Alberta residents.

CONCLUSIONS

We have assessed the impact of a carbon tax on the Alberta economy. Our simulations show that the effect is quite clearly negative with the magnitude depending critically on factors such as who gets the tax revenue, how flexible are labour markets, and the extent to which lower priced fossil fuels can be substituted for higher priced ones. The costs of this tax, or any variant specifically focused on carbon, would be large for Albertans.

REFERENCES

Alberta (1993), "Annual Report of Province of Alberta". Form 18-K, Securities and Exchange Commission, Washington, D.C

Alberta (1994), *Budget '94: Securing Alberta's Future*, Jim Dinning, Provincial Treasurer

Chambers, Edward J., and Michael Percy (1992) *Western Canada in the International Economy*, (University of Alberta Press, Edmonton)

Dixon, Peter, B. R. Parmenter, John Sutton, and D. P. Vincent (1982), *Orani: a Multisectoral Model of the Australian Economy*,(North Holland Publishing, Amsterdam)

DRI Canada and Marbek Resource Consultants (1993), "Canadian Competitiveness and the Control of Greenhouse Gas Emissions Through Imposition of a Carbon Tax"

Energy Council of Canada (1994) *Energy for Tomorrow's World*

Harrison, D. and A. L. Nichols (1991) *Market-based Approaches to Managing Air Emissions in Alberta*, Discussion paper prepared for Alberta Energy, Alberta Environment and Canadian Petroleum Association

Nordhaus, William D (1993) "Reflections on the Economics of Climate Change" *Journal of Economic Perspectives* (Vol 7:4, 11-25)

Norrie, Kenneth and Michael Percy (1983) "Freight Rate Reform and Regional Burden", *Canadian Journal of Economics*, (XVI:2, 325-49)

Olgus, Ayla (1994) "Modelling the Impact of a Carbon Tax on Alberta", Department of Economics, University of Alberta

Percy, Michael B (1994) *Modelling the Alberta Economy*, Report prepared for Farming for the Future.

Rheaume, Gilles (1993) "The Challenge of Climate Change, Policy Options for Canada" Conference Board of Canada, Business and Environmental Research Program