

# **Impacts of climate policy on the international competitiveness of Canadian industry: How big and how to mitigate?**

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## **Introduction**

International negotiations on climate change have progressed under the principle that nations face “common but differentiated responsibilities” for greenhouse gas (GHG) emission mitigation (United Nations 1992). As a result, it is likely that for the foreseeable future, emission reduction targets in developed countries will remain more aggressive than those in developing countries. Even within the group of developed countries, significant differences in the stringency of climate change policies may persist as countries adopt different emission reduction burdens, or as a result of particular national circumstances.

To the extent that more aggressive GHG abatement increases the cost of producing goods and services, persistent differences in policy stringency between countries could have important implications for competitiveness and for the effectiveness of the policies (Babiker and Rutherford 2005; Fischer and Fox 2008; Ismer and Neuhoff 2007). First, differences in abatement efforts could lead corporations to shift production away from more stringently regulated countries into less regulated countries. In turn, this could lead to loss of employment and economic output, and deterioration in the terms of trade in the more aggressively regulated countries. Fears of this type of competitiveness impact undermine the support for abatement policy in developed countries.

In addition to these economic impacts, a shift of production from the more stringently regulated country to less constrained economies can significantly reduce the environmental effectiveness of

the policy. Since the greenhouse gases responsible for climate change are a global pollutant whose effect is independent of location of emissions, simply shifting production from one country to another does not improve the environment. To the extent that firms shift location to avoid regulation, the environmental effectiveness of the policy is reduced. This phenomenon is usually referred to as emissions leakage.

The environmental effectiveness of sub-global policies can be further lessened because of the rebound effect. As consumption of fossil fuels decreases in the stringently regulated country, world demand for fossil fuels falls, which should result in a reduction of their price. In turn, this should lead to additional consumption of fossil fuels in less regulated countries, which increases global emissions and further reduces the effectiveness of the policy.

These concerns over competitiveness and environmental effectiveness have probably slowed the implementation of climate policies in developed countries. If stakeholders in those countries feel that aggressive climate change abatement efforts are likely to reduce economic competitiveness without improving environmental outcomes, support for the policies will understandably diminish.

This paper focuses on competitiveness impacts of climate change policies in Canada.

Competitiveness concerns have been at the forefront of national debates about Canadian climate policy. Canada's energy intensity of over 13,000 Btu per US dollar is significantly greater than that of the US (8,841), France (6,596), Japan (6,492), and almost every other developed country (Energy Information Administration 2008). In addition, Canada's economy is particularly open to international trade. While total trade (the sum of imports and exports measured in units of

domestic currency) is equivalent to roughly 70 percent of Canada's gross domestic product, it amounts to only about 55 percent in most European countries, and less than 30 percent for Japan and the US (Foreign Affairs and International Trade Canada 2008). Canada's openness to trade and energy intensive economy mean that it could be especially susceptible to erosion of international competitiveness following imposition of carbon pricing.

The paper seeks to provide insight on two related questions. First, to what extent is competitiveness an issue for Canada's energy-intensive sectors in developing climate policy? Second, if competitiveness is an issue, what policies could Canada pursue that would reduce the impacts of domestic climate policy on the competitiveness of those sectors? The paper begins by reviewing the literature on the competitiveness implications of environmental policy. A model used to evaluate impacts of carbon pricing on competitiveness is then described. Finally, the model is used to answer the two questions described above.

### **Previous literature on the link between climate policy and competitiveness**

Previous empirical work exploring the competitiveness implications of environmental policy has used both econometric and modeling techniques. Tobey (1990) provides an early econometric analysis. He employs a cross section and panel analysis to measure whether environmental regulation influences trade patterns in a sample of developed and developing countries. Neither approach yields estimates supporting the hypothesis that more stringent environmental regulations cause changes in net exports from a country. These results were echoed several years later by Jaffe et al., who surveyed over 100 empirical studies of the relationship between environmental regulation and international trade and found that "Overall, there is relatively little evidence to support the hypothesis that environmental regulations have had a large impact on

competitiveness...” (Jaffe et al. 1995, p.157). More recently, researchers conducting ex post analysis of the first phase of the European Union’s Emission Trading Scheme failed to find a positive correlation between EU permit prices and imports of energy-intensive products from abroad (Baron et al. 2008). At least in part, these findings could be due to the fact that data to support econometric studies of the link between competitiveness and environmental policy is patchy, especially for developing countries that have significantly different environmental regulations than more developed countries.

In contrast to econometric studies, the numerical modeling studies that have explored sub-global greenhouse gas mitigation agreements like the Kyoto Protocol have typically found a strong link between competitiveness and the adoption of environmental policy. For example, using a standard multi-region static general equilibrium model, Babiker and Rutherford (2005) project that production of energy-intensive commodities in parties bound by the Kyoto Protocol would decline by about 2 to 5 percent relative to projected levels during the first commitment period, while production would increase in other countries. Impacts in Canada are projected to be higher – the same study suggests a 10 to 15 percent reduction in Canadian production and exports of energy intensive commodities following implementation of Kyoto. Using a similar multi-region static general equilibrium model, Wigle (2001) reports that Canadian production of energy-intensive goods would decline by roughly 1 to 5 percent if Kyoto targets were achieved. By changing some key assumptions in the basic model relating to trade elasticities and market structure, Babiker (2005) finds that these impacts could dramatically increase. In particular, by assuming that traded products are homogeneous rather than differentiated according to country of production, he finds that the competitiveness of heavy industrial manufacturing firms in countries bound by the Kyoto Protocol could decline by as much as 75 percent relative to projected future

levels. Fischer and Fox (2008) use a partial equilibrium model and find roughly 2 to 8 percent reduction in Canadian production of energy-intensive products associated with a modest (\$14/t CO<sub>2</sub>) carbon price.

Most of these papers use global models, in which very little disaggregation of Canadian industrial structure is included. In addition, most previous analysis has been conducted using static models, in which capital availability is given exogenously. This paper uses a fairly disaggregate dynamic model, in which the capital stock evolves endogenously based on the investments of forward-looking economic agents. The remainder of this paper is a numerical analysis of the likely extent of competitiveness impacts following the adoption of climate policy in Canada. In addition, this paper systematically evaluates the impact of alternative policy design options on competitiveness.

### **The model**

The model is a single-region dynamic general equilibrium model of the Canadian economy. A forward-looking representative household is endowed with an exogenously increasing labour supply calibrated to an external forecast, and an initial capital stock that accumulates over time through endogenous savings and investment decisions. The household provides labour and capital services to firms, who combine these with intermediate material and energy inputs to produce commodities. Commodities can either be consumed domestically or exported to world markets under the assumption that Canada is a small open economy that does not affect world prices for commodities. A government agent is also specified, which collects all taxes in the model, and which produces an exogenously given level of government services. Important aspects of the model are described in the following sections.

## Household

The representative household is forward-looking, and chooses consumption to maximize discounted utility:

$$\max_{c_t} U = \sum_{t=1}^T \left( \frac{1}{1+\rho} \right)^t u(c_t) \quad (1)$$

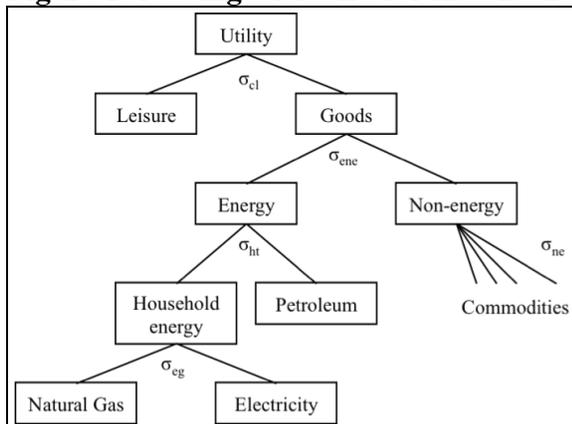
where  $T$  is the time horizon of the model,  $\rho$  is the rate of pure time preference,  $c_t$  is consumption, and  $u(c_t)$  is the instantaneous utility of consumption, given by:

$$u(c_t) = \frac{c_t^{1-\theta} - 1}{1-\theta} \quad (2)$$

Where  $\sigma_t = 1/\theta$  is the elasticity of intertemporal substitution.

Instantaneous consumption is based on a nested constant elasticity of substitution function, as shown in Figure 1, where  $\sigma_n$  is the elasticity of substitution for nest  $n$ . This structure imposes an endogenous labour supply in the model, as households are able to adjust their provision of labour in response to the after-tax wage rate. In addition, the detailed nesting of energy commodities allows more realistic response of consumer demand in response to changing relative energy prices.

**Figure 1: Nesting structure for instantaneous utility**



The consumer maximizes intertemporal utility such that the intertemporal budget balances:

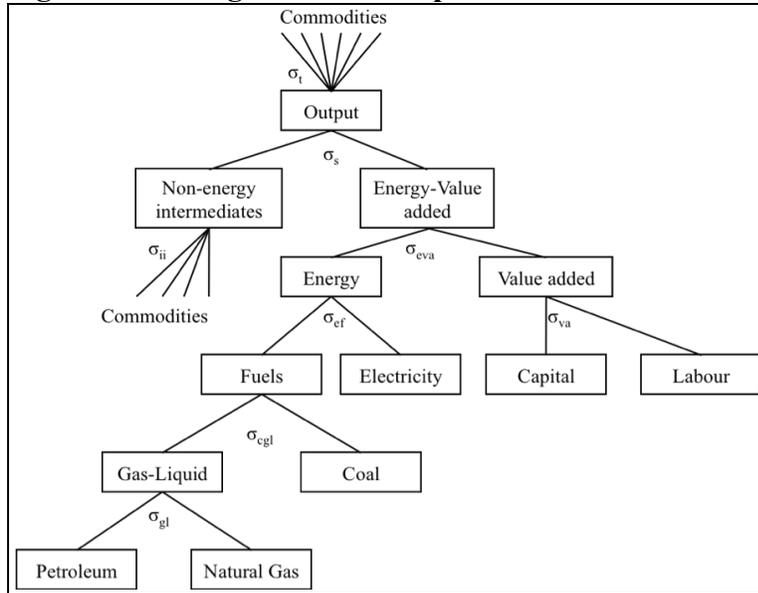
$$\sum_{t=1}^T \sum_i p_{it} g_{it} (1 + tc_{it}) = \sum_{t=1}^T \left( \frac{(L_t - l_t) w_t}{1 + td_{lt}} \right) + TRN_t + \frac{K_0 r_0}{1 + td_{k0}} - \frac{K_T r_T}{1 + td_{kT}} \quad (3)$$

Where  $p_{gt}$  are the prices of good  $g$  in period  $t$ ,  $tc_{it}$  are the taxes on final consumption,  $TRN_t$  represents lump sum transfers from government to households,  $L_t$  is the total labour endowment,  $l_t$  is the leisure consumption,  $w_t$  is the gross wage rate,  $td_{lt}$  is the direct tax on labour income,  $td_{kt}$  is the direct tax on capital income,  $r_t$  is the rental rate on capital, and  $K_t$  is the capital stock. The final two terms on the right hand side represent the value of the initial capital stock and the post-terminal capital stock, respectively.

### *Production*

Production of goods in each sector  $j$  in each time period is given by a constant returns to scale, constant elasticity of substitution function, with nesting designed to represent detailed substitution possibilities associated with energy consumption and emissions. The nesting structure is given in Figure 2, where  $\sigma_m$  is the elasticity of substitution within nest  $m$  (sector subscripts have been dropped for clarity). Corresponding to the rectangular structure of Canada's input-output tables, the nesting structure allows multiple commodities to be produced by each sector. Choice of commodity production in each sector is governed by a constant elasticity of transformation function, with elasticity of transformation  $\sigma_j$ .

**Figure 2: Nesting structure for production**



Producers maximize profits, and profits for each sector are zero in equilibrium:

$$\pi_j = p_j Y_j - rK_j(1 + tf_k) - wl_j(1 + tf_l) - \sum p_{in} in_j \quad (4)$$

where  $p_j$  is the price of output,  $tf_j$  is the net input tax rate on factors of production,  $p_{in}$  is the price of inputs, and  $in_j$  is the quantity of inputs.

### Government

One government agent represents all three levels of Canadian government (federal, provincial, and municipal). Government collects net tax revenue (less subsidies), including both direct and indirect taxes. Taxes included in the model are (1) a direct labour income tax and (2) a direct corporate income tax, (3) an indirect factor input tax/subsidy on producers, (4) a consumption tax on final consumption and investment, and (5) import tariffs. The rates of all indirect taxes and subsidies are calibrated to the input output data, while the rates for direct taxes are derived from separate data on direct income taxation. All taxes are assumed to remain constant throughout the simulation unless endogenously modified (as described in the text). When a carbon price is applied, government is considered the owner of emission permits (or the collector of tax receipts,

in the case of a carbon tax) unless otherwise noted.

Government expenditures finance provision of an aggregate public good (health, education, defense, etc.). In all simulations, provision of the aggregate public good remains constant at reference case levels. Remaining government budget is transferred to households in lump sum unless otherwise specified. Government is subject to an intertemporal budget constraint such that all net tax revenue is balanced by expenditures and transfers.

### *Trade*

To allow for cross-hauling, the model uses an Armington formulation for international trade in which domestically and internationally produced goods are treated as imperfect substitutes. In particular, each domestic consumption good  $i$  is a constant elasticity of substitution aggregate of domestic and foreign goods:

$$A_i = \left( \alpha_{hf,i} h_i^{\gamma_{hf,i}} + (1 - \alpha_{hf,i}) f_i^{\gamma_{hf,i}} \right)^{1/\gamma_{hf,i}} \quad (5)$$

Where  $A_i$  is the Armington aggregate,  $h_i$  and  $f_i$  are the quantities of domestic and foreign good, respectively,  $\alpha_{hf}$  is a constant determined through calibration, and where  $\sigma_{hf,i} = 1 / (1 - \gamma_{hf,i})$  is the Armington elasticity. For exports, a similar constant elasticity of transformation is applied to each domestic production industry:

$$Y_j = \left( \alpha_{dx,i} d_i^{\gamma_{dx,i}} + (1 - \alpha_{dx,i}) x_i^{\gamma_{dx,i}} \right)^{1/\gamma_{dx,i}} \quad (6)$$

where  $d_i$  and  $x_i$  are the quantities of domestically produced good for domestic and export markets, respectively,  $\alpha_{dx}$  is a constant determined through calibration, and where  $\sigma_{dx,i} = 1 / (1 - \gamma_{dx,i})$  is the domestic-export transformation elasticity.

Trade in commodities is mediated through the foreign exchange market, which allows Canadian

currency to appreciate or depreciate relative to foreign currencies. In each period, the model requires balance in the foreign exchange market relative to the reference case scenario (in which there is a balance of trade surplus).

### *Factor markets*

Household labour supply is assumed to grow at an exogenous rate, determined by exogenous federal government forecasts of population and labour productivity growth. As described in the section on consumer utility, the labour supplied to production is endogenous, since consumers can choose leisure consumption as a function of the real wage rate. Labour is treated as an aggregate, is assumed to be perfectly mobile between sectors, and the labour market is assumed to be perfectly competitive.

The capital stock owned by households in the first period is determined by calibration to the benchmark data set. Thereafter, the capital stock evolves endogenously, based on savings and investment decisions, as described in the following section. The initial capital stock owned by households is assumed to be sector-specific fixed capital. Vintages of capital installed during a model run are assumed to be perfectly malleable between sectors.

### *Dynamics*

Consumers endogenously choose how much of total output to invest in a given period. The capital stock evolves subject to these investments:

$$K_{t+1} = K_t \cdot (1 - \delta) + I_t \tag{7}$$

where  $K_t$  is the total capital stock in time  $t$ ,  $\delta$  is the rate at which the capital stock depreciates, and  $I_t$  is the total investment in period  $t$ . Overall investment is a constant elasticity of substitution

aggregate of investment goods:

$$I = \left( \sum_i \alpha_{li} A_{li}^{\gamma_i} \right)^{1/\gamma_i} \quad (8)$$

where  $\alpha_{li}$  is a calibrated constant,  $A_{li}$  is the quantity of Armington commodity  $i$  used for investment, and where  $\sigma_I = 1 / (1 - \gamma_I)$  is the elasticity of substitution between investment commodities.

Investment is a ‘zero-profit’ activity:

$$r(1 + \phi)I - \sum_i p_i A_{li} (1 + t_i) = 0 \quad (9)$$

where  $\phi$  is the interest rate, and  $t_i$  is the ad valorem tax on investment demand for good  $i$ .

Because the model has a finite horizon, a constraint is needed for final period investment.

Following Lau et al. (2002), the following constraint is used:

$$\frac{I_T}{I_{T-1}} \geq \sum_J \frac{Y_{jT}}{Y_{jT-1}} \quad (10)$$

### *Emissions*

Greenhouse gas emissions are directly proportional to combustion of fossil fuels.<sup>1</sup> An autonomous energy efficiency index is adopted to simulate technological change, and AEEI parameters are set at a sectoral level according to Bataille et al. (2006). Emissions policy is simulated by requiring all emitters of fossil fuels to hold a permit (or pay a tax) for each unit of

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<sup>1</sup> The following coefficients are used: coal: 0.085 tonnes CO<sub>2</sub>/GJ, refined petroleum products: 0.707 tonnes CO<sub>2</sub>/GJ, natural gas: 0.05 tonnes CO<sub>2</sub>/GJ. The fixed link between CO<sub>2</sub> emissions and fuel consumption implies that carbon capture and storage is not explicitly included in the model.

greenhouse gas emitted. Because of the detailed nesting structure adopted, emitters have a choice of substituting between fuel types or improving energy efficiency in order to avoid emissions. Unless otherwise noted, emission permits are initially owned by government and are distributed to emitters in lump sum. The permit market is assumed to be perfectly competitive.

### *Data and calibration*

The model includes a medium level of disaggregation in production sectors and commodities, as shown in Table 1. The level of aggregation is chosen to balance a relatively high level of useful detail with the computational requirements imposed by a fully dynamic model.

**Table 1: Commodity and sector disaggregation**

Commodities		Sectors	
agg	agricultural products	agr	agriculture
frs	forestry products	log	forestry and logging
pri	products of primary industries	fsh	fishing and hunting
min	non-energy mine products	oag	oil and gas extraction
col	coal	mng	mining
oil	crude oil	elc	electricity generation
ngas	natural gas, including distribution	ngd	natural gas distribution
mfd	manufactured food products	cns	construction
oma	other manufactured products	oman	other manufacturing
pap	pulp and paper products	ppr	pulp and paper manufacturing
met	primary and fabricated metal products	rpp	petroleum product manufacturing
chm	chemical products	chem	chemical product manufacturing
cem	cement and lime	ind	industrial mineral manufacturing
gas	gasoline	mtl	metal product manufacturing
die	diesel	wrt	wholesale and retail trade
orp	other refined petroleum products	tran	transportation
lp	liquified petroleum gases	serv	service sectors
con	construction	gs	government services
trn	public and freight transportation		
whl	storage, warehousing, wholesaling		
ser	all services		
ele	electric power		
cok	coke		
wat	water from utilities		
ret	retail margins		

Data on the financial flows underlying the model is derived from the annual economic accounts published by Statistics Canada (tables 381-0009 and 381-0010). The economic accounts data in Canada is structured as a rectangular matrix (in which each sector can produce multiple commodities), and this structure is maintained in the model development. The economic accounts data is supplemented with additional data on direct taxation (Statistics Canada table 385-0001), energy consumption (Statistics Canada tables 128-0002 and 128-0009), and greenhouse gas

emissions coefficients (Natural Resources Canada 2006).

As is common in applied general equilibrium analysis, a calibration procedure is adopted, where data on historical transactions in a benchmark year is used in combination with exogenous elasticity values to parameterize the consumer utility function and production functions. The year 2000 is used as the benchmark data year in the results presented here, but other years are tested to ensure the model results are robust to changes in specification of the benchmark year. Parameters used in the model runs, as well as the sources for the parameter values, are given in the Appendix.

### **Scenarios and results**

To assess the competitiveness impacts that could be associated with unilateral implementation of aggressive climate change policy in Canada, I first consider a scenario in which a carbon price – imposed using either a cap and trade system with auctioned permits or a tax system – is applied in Canada on all combustion greenhouse gas emissions arising during both production and final consumption. No carbon price is levied on embodied carbon in either imported or exported goods. However, exporters are required to pay the carbon price on any emissions produced during the manufacturing process in Canada, or to absorb costs associated with emissions abatement. Because the carbon price is unilateral, foreign firms importing into Canada are not required to absorb such costs. This difference is what can generate impacts on the competitiveness of domestic firms.

In this scenario, revenues from the domestic carbon price are recycled in lump sum from the government to the household, such that government spending on public goods remains at

reference case levels. The level of carbon price is set endogenously in the model to be consistent with achievement of 2020 emission reduction targets proposed by the federal government (Environment Canada 2008; Government of Canada 2008). These require a 20 percent reduction in emissions from 2006 levels by 2020, which likely represents a 30 to 35 percent reduction compared to business as usual levels in 2020. To allow the model to converge to a steady state, in years following 2020 the model requires that abatement remains at the same level relative to business as usual emissions as in 2020.

At an aggregate level, the results produced by the model are consistent with other general equilibrium analyses of Canadian climate policy. For example, in the scenario described here, Table 2 shows that the model suggests a welfare loss of about 1 percent due to the application of carbon pricing, and a loss of gross domestic product relative to projected business as usual levels reaching almost 4 percent in 2020 (this is the year of peak economic impact, and the impacts both before and after 2020 are significantly less than this). This is consistent with the analysis by Dissou et al. (2002), who use a dynamic CGE model to assess the consequences of Canada achieving its Kyoto Protocol target, and with Wigle (2001), who uses a static CGE to assess the same target.<sup>2</sup> Likewise, the level of carbon price, at about \$100/t CO<sub>2</sub>, is fairly close to the levels suggested in these studies and others (Bataille et al. 2006), once the relative stringency of targets is taken into account.

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<sup>2</sup> Although the timelines of the Kyoto Protocol targets considered by Wigle (2001) and Dissou et al. (2002) are similar to the one considered here (both consider a timeline of about 10 years between initial policy implementation and the target), it is likely that the emission reduction target considered in this paper requires a somewhat larger cut in emissions relative to projected trends than the target analyzed in Wigle or Dissou et al.

Table 3 shows the projected results of this policy on the competitiveness of Canada's productive sectors, measured as the change in sector gross domestic product caused by changes in net exports induced by the policy. In absolute terms, the upstream oil and gas, transportation, and metal, basic chemical, and petroleum product manufacturing sectors appear likely to lose the most market share to foreign competitors. Relative to sector value added, the industrial minerals sector appears particularly vulnerable. Unsurprisingly, these sectors are all energy intensive, so costs of production increase fairly rapidly with rising carbon prices. Additionally, all of these sectors are relatively trade exposed, so that increases in production cost can result in loss in market share to international competitors.

Much of the loss in these sectors is made up for, however, by increases in the net exports of less energy intensive sectors – in particular the light manufacturing, service, and mining sectors.<sup>3</sup>

These sectors effectively benefit from the reduction in competitiveness of the energy-intensive sectors. In particular, the reduction in net exports in the latter causes the foreign exchange rate to fall, increasing competitiveness of the former. Likewise, the policy-induced reduction in output of the energy-intensive sectors reduces input demands, thereby lowering their prices, again to the benefit of less energy-intensive firms. As described by Jaffe et al. (1995), this cannot strictly be considered a positive competitiveness impact; instead it results from general equilibrium impacts of the policy on the wage rate, allocation of capital, and foreign exchange rate. Nonetheless, the fact that net exports from these sectors are likely to increase in response to an aggressive carbon price should dampen the potential negative impacts related to loss of competitiveness in the

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<sup>3</sup> The particularly large increase in net exports from the mining sector results mostly from changes in the coal market. The carbon tax induces steep declines in the domestic demand for coal, such that domestic producers export a greater proportion of their product, and such that Canadian demand for imports drops.

energy intensive sectors.

### **Addressing competitiveness impacts of climate policy**

Based on the preceding analysis, there appears to be legitimate cause for concern that the most energy intensive sectors of the Canadian economy could become less competitive relative to international firms in the event of the introduction of an aggressive Canadian carbon price in the manner described above. Fears of such impacts, and the corresponding losses in employment, could therefore undermine the support for carbon pricing in Canada. In addition, to the extent that production of energy intensive commodities shifts from Canada to other countries without a carbon price, the aim of the policy is partly subverted. When sub-global carbon pricing policies are considered, it therefore may make sense to consider policies to reduce the chance that production will shift to countries without a carbon price. Several measures are available that could reduce the competitiveness impacts of unilateral climate change policy. I discuss these in the following sections and use the model to evaluate their effectiveness in mitigating the negative competitiveness impacts found in the first scenario.

#### *Revenue recycling*

In the first scenario that was considered, revenues raised from carbon pricing were transferred directly from government to households. A frequently discussed alternative to lump sum transfers involves using revenue from carbon pricing to lower other taxes – for example the tax on income to labour or capital – while maintaining the government budget constant. Most analyses suggest that this type of revenue recycling is likely to stimulate more economic activity compared to recycling in lump sum, because it can reduce the deadweight loss associated with taxation (Bovenberg and De Mooij 1994; Goulder 1995). Some analyses even suggest, particularly at low carbon prices, that a fiscally-neutral carbon price with revenue recycling could stimulate

economic growth overall (Bento and Jacobsen 2007; Edwards and Hutton 2001; Parry and Bento 2000).

This type of policy is attractive because it is simple to administer, unlikely to conflict with international trade rules, and may improve the political acceptability of carbon pricing. However, although revenue recycling is likely to stimulate overall economic growth compared to lump sum transfers, it may not stimulate growth in those sectors that are particularly impacted by carbon pricing.

Intuitively, a revenue recycling scheme will most help those sectors that are relatively intense in the factor in which taxes are cut, and which produce few emissions; by definition, these are unlikely to be those most impacted by a carbon price. For an illustration, consider the cost function for sector  $j$ , derived from the first order conditions obtained from the production function in Figure 2 assuming profit maximization under perfect competition:

$$c_j = c_j(p_K, p_L, \mathbf{p}_E, \mathbf{p}_M) \quad (11)$$

where  $p_K$ ,  $p_L$ ,  $\mathbf{p}_E$ , and  $\mathbf{p}_M$  are the prices paid by the producer for capital, labour, energy, and materials, respectively (bold font signifies a vector). A labour tax ( $t_L$ ) creates a difference between prices paid by the producer and those received by the household provider of labour.

Likewise, the price on carbon increases the price of energy proportionally to its carbon intensity, such that the cost function becomes:

$$c_j = c_j(p_K, (1 + t_L)w_L, \mathbf{p}_E + \mathbf{e}\tau, \mathbf{p}_M) \quad (12)$$

where  $w_L$  is the price received by the household for supply of labour,  $\mathbf{e}$  is the carbon intensity of energy, and  $\tau$  is the carbon price. If government uses the revenue raised from the carbon price to lower the tax on labour income, such that  $t_L = f(\tau)$ , the change in the cost of production for sector

$j$  is given by:

$$dc_j = \frac{\partial c_j}{\partial p_K} dp_K + \frac{\partial c_j}{\partial p_L} \cdot \left( w \frac{\partial f}{\partial \tau} d\tau + t_L dw \right) + \frac{\partial c_j}{\partial p_E} (e d\tau + dp_E) + \frac{\partial c_j}{\partial p_M} dp_M \quad (13)$$

In general equilibrium, all prices adjust in response to a policy change, making the effect of a revenue-neutral tax shift difficult to discern analytically. By abstracting from general equilibrium considerations, it is possible to estimate the conditions under which labour tax recycling can improve the competitiveness of the sector. This occurs when:

$$\frac{\partial c_j}{\partial p_L} \frac{\partial f}{\partial \tau} + \frac{\partial c_j}{\partial p_E} e < 0 \quad (14)$$

Application of Shepherd's Lemma gives  $L = \partial c / \partial p_L$  and  $E = \partial c / \partial p_E$ , where  $L$  and  $E$  are the inputs of labour and energy, respectively, per unit of production. For small tax shifts, evaluation of this equation using Canadian industry data on input structure suggests that a carbon price with labour tax recycling is likely to reduce costs in the mining, light manufacturing, wholesale/retail trade, service, and government sectors.<sup>4</sup> To the extent that these sectors are exposed to competition from foreign firms, this should improve their competitiveness. Other sectors would continue to face net increases in costs from carbon pricing, even with labour tax recycling. The greatest beneficiaries from labour tax recycling, in other words, are those sectors least exposed to the international competitiveness impacts from carbon pricing.

As suggested above, however, we expect all prices to adjust in equilibrium, not just tax rates.

When this flexibility is introduced, the general equilibrium model described above suggests that revenue recycling – where carbon price revenues are used to cut either labour or capital taxes – is

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<sup>4</sup> The form of  $\partial f / \partial \tau$  is determined from the marginal abatement curve produced by the model, and from the labour taxation rate:  $\partial f / \partial \tau = -0.0008$ . In other words, a \$1/t CO<sub>2</sub>e carbon tax would result in a labour tax rate 0.08 percentage points lower.

unlikely to significantly alter the likely changes in competitiveness found in the original scenario, where revenue from the carbon price was recycled in lump sum to emitters – a confirmation of the simple analysis described above using the cost function. Full results at a sector level are given in Table 3.

As in other analyses however, the model here does suggest that appropriate revenue recycling is likely to significantly mitigate the overall economic impact of carbon pricing, as shown in Table 2. In particular, using carbon price revenues to cut the existing capital tax appears likely to reduce the overall economic impact of the policy by around 50 percent, for the carbon prices considered here.

#### *Sector exemptions*

Other types of policies do directly target the competitiveness impacts of carbon pricing. In countries that have implemented carbon pricing, sectoral exemptions are often used to protect internationally competitive industries from the policy. For example, Norway, which implemented a carbon tax in 1991, exempts the metals and cement sectors entirely from the tax, and offers much reduced tax rates for the pulp and paper sector and some other heavy industries (Bruvoll and Larsen 2004). Sweden provided similar exemptions for industry in general, and in particular for energy-intensive industry, when it introduced its carbon tax in the same year (Johansson 2006).

While this type of policy should be effective in preserving output and employment in the exempted sectors, it comes at a cost. Bohringer and Rutherford (1997) and Wigle (2001) suggest that sectoral exemptions from a carbon tax significantly increase the welfare cost of achieving a given emission reduction target in Germany and Canada, respectively, because the narrowing of

the tax base means that the carbon tax has to rise significantly higher in other sectors. In addition, there could be practical difficulties associated with the implementation of sectoral exemptions, especially because information required by government to ascertain appropriate sectors to exempt from climate policy is difficult to obtain directly, and because the public may be opposed to sectoral exemptions in some cases. Hoel (1996) further notes that sectoral tax differentiation may be contrary to international trade laws.

Table 3 illustrates the projected change in competitiveness of Canadian sectors, given exemptions for the industrial minerals, oil and gas extraction, and petroleum refining sectors: those sectors facing the largest competitiveness challenges in the original scenario.<sup>5</sup> The results suggest, unsurprisingly, that sector exemptions are effective in preserving the competitiveness of exempted sectors. For example, although the industrial minerals sector is expected to suffer significant negative competitiveness impacts in the original lump sum scenario, if it is granted an exemption from the policy, it is likely to gain market share at the expense of foreign competitors, as a result of reduction in costs of other inputs.

However, as has been found in the other studies referenced above, sector exemptions significantly exacerbate the overall economic impacts of the policy. Because the carbon price is required to rise higher owing to the narrower base for emission reductions, competitiveness impacts are amplified in non-exempted sectors. The higher carbon price also increases the overall negative impacts of the policy. Table 2 suggests that exemptions are likely to increase negative impacts on welfare, consumption, wages, and other key variables.

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<sup>5</sup> In this analysis, the sectors chosen for exemptions were exogenously given, such that firm behaviour could not influence the availability of an exemption.

### *Output-based rebating*

An alternative to sectoral exemptions is a policy in which the carbon price is applied to all sectors without exemptions, but where the revenue raised through carbon pricing is dynamically allocated to producers. This can be accomplished by allocating emission permits to firms according to an index of economic or physical output, or directly through a carbon tax accompanied by subsidies indexed to output. The policy provides similar incentives as an intensity-based regulation, and can be implemented as such (Fischer and Fox 2007). The proposed Canadian policy regulating emissions from large industrial emitters is effectively a cap and trade system with output-based allocation of emission permits (Government of Canada 2008).

This form of policy preserves the incentive for domestic firms to reduce emissions associated with each unit of production, but eliminates the incentive for domestic firms to curtail production to meet emission targets. The introduction of output-based permit allocations introduces an additional distortion into the permit market related to the output subsidy, and may reduce the transparency of the policy to the public, but may help to preserve domestic production in the case where climate policy is implemented unilaterally, as is considered here (Bernard, Fischer, Fox 2007).

Several variants of output-based rebating schemes are possible. I consider a “baseline and credit” system, in which government sets a baseline emission intensity for each sector,  $b_j$ . Firms that reduce their emission intensity below the baseline intensity create tradable credits, while firms that are unable to reduce emissions to the baseline intensity are required to purchase tradable credits to make up the gap. As a result, the cost function becomes:

$$c_j = c_j(p_K, p_L, p_E + e\tau, p_M) - b_j \cdot \tau \quad (15)$$

The policy-induced change in cost of production is therefore:

$$dc_j = \left( \frac{\partial c_j}{\partial p_K} dp_K + \frac{\partial c_j}{\partial p_L} dp_L + \frac{\partial c_j}{\partial p_E} (ed\tau + dp_E) + \frac{\partial c_j}{\partial p_M} dp_M \right) - b_j \cdot d\tau \quad (16)$$

Again abstracting from general equilibrium considerations, it is possible to derive the change in costs imposed by a marginal increase in the carbon permit price, when output-based recycling is used:

$$dc_j = \frac{\partial c_j}{\partial p_E} ed\tau - b_j \cdot d\tau \quad (17)$$

Application of Shepherd's Lemma gives  $dc_j = (B_j - b_j)d\tau$ , where  $B_j$  is the sectoral emission intensity in the absence of any policy. The incremental cost of a marginal increase in carbon price is therefore directly correlated with the baseline chosen by government (effectively the allocation of free permits). For non-marginal increases in carbon price, costs further decline as the sector is able to reduce its carbon intensity. As a result, cost reductions are likely for sectors with a relatively lower marginal cost of abatement. In many cases, these sectors are the most emission intensive sectors – in particular the large industrial sectors – which are responsible for the majority of emissions. These sectors are precisely the sectors most likely to face competitiveness impacts under the lump sum recycling scheme, so it is likely that output-based rebating can effectively address competitiveness issues.

Table 3 uses the general equilibrium model to confirm that output-based recycling can significantly mitigate the competitiveness impacts of unilateral climate policy, which has also been demonstrated analytically by Bernard et al. (2007). Compared to the initial scenario with lump sum recycling of emission permits, as well as to the revenue recycling scenarios, the output-based recycling scheme looks likely to cut competitiveness impacts for the energy-

intensive sectors by around half. In addition, although output based recycling requires a higher carbon price and introduces other distortions, the results in Table 2 show that the policy can better maintain economic output and welfare than lump sum recycling of revenues.

#### *Border tax adjustments*

Finally, border tax adjustments have been discussed as a potentially appropriate way to reduce the leakage and competitiveness impacts of unilateral climate policy (Hoel 1996). Export rebates could be used to protect the competitiveness of Canadian firms in international markets and import tariffs could be used to protect the competitiveness of Canadian firms in domestic markets. These adjustment schemes are likely to be effective in preserving the market share of Canadian firms, but it remains unclear whether they are compatible with world trade law (Babiker and Rutherford 2005; Fischer and Fox 2008; Ismer and Neuhoff 2007; van Asselt and Biermann 2007).

Practical implementation of border tax measures could also be challenging. Accurately measuring embodied carbon in imports and exports would be extremely difficult, especially in the case of heterogeneous commodities. Additionally, to the extent that such protectionist measures induce retaliatory measures by other countries, they could in fact reduce the competitiveness of Canadian firms, which are emission-intensive in comparison to most trade partners.

Despite likely implementation difficulties, Table 3 suggests that both an import tariff and an export rebate could be effective in maintaining the market share of Canadian firms following imposition of domestic carbon pricing. The combination of both policies seems likely to virtually eliminate competitiveness impacts. Such policies are likely to be costly to consumers however. The import tariff in particular raises the price of imports, thus reducing consumption and welfare.

The export rebate stimulates output by exporters, which implies a higher carbon price and thus transfers the distribution of emission reductions to other sectors.

**Table 2: Selected results of policies to protect international competitiveness of Canadian industries, 2020**

	Revenue Recycling			Border Adjustments			Exemptions	Output-based Allocations
	Lump Sum	Labour Tax	Capital Tax	Import Tariff	Export Rebate	Both		
Real CO <sub>2</sub> Price (\$/t CO <sub>2</sub> )	105.43	105.89	115.29	101.72	152.51	160.56	144.61	142.42
Equivalent variation (discounted full consumption)	-0.82	-0.78	-0.40	-1.09	-0.97	-1.11	-0.89	-0.74
Discounted consumption	-0.95	-0.83	-0.44	-1.28	-1.13	-1.33	-1.04	-0.79
Emission reduction	-35.62	-35.62	-35.62	-35.62	-35.62	-35.62	-35.62	-35.62
Emission reduction, industry	-39.66	-39.67	-39.65	-39.54	-38.69	-38.40	-38.96	-38.08
Emission reduction, household	-19.71	-19.65	-19.71	-20.17	-23.52	-24.64	-22.45	-25.91
Labour supply (hours)	-0.10	-0.01	-0.31	-0.18	0.03	-0.08	-0.15	0.34
Real after-tax wage rate	-5.70	-3.92	-3.19	-8.58	-7.48	-10.48	-7.56	-2.49
Consumer price index	1.97	1.85	-3.04	2.95	2.85	3.87	2.51	1.75
Real exports	-0.17	-0.21	-3.82	-4.20	-0.15	-6.44	-1.78	-2.24
Real imports	-0.60	-0.62	-3.92	-0.50	-3.31	-6.47	-2.33	-2.47
Real foreign exchange rate	0.60	0.60	0.00	0.84	-1.65	-3.93	0.01	-1.05
Real GDP at market prices	-3.96	-3.88	-1.97	-6.55	-2.99	-5.53	-3.82	-3.25

*Note: All values measured in percentage change from reference case scenario unless otherwise noted. All results are given for the year 2020 only, except where discounted values are given.*

**Table 3: Change in sector value added due to change in net exports, 2020**

	Revenue Recycling			Border Adjustments			Exemptions	Output-based Allocations
	Lump Sum	Labour Tax	Capital Tax	Import Tariff	Export Rebate	Both		
agr	-7.30	-7.33	-6.97	-6.93	-3.40	-0.96	-9.95	-1.64
log	-0.03	-0.04	-0.16	0.25	-0.18	-0.05	-0.26	-0.04
fsh	-2.40	-2.39	-4.76	-0.77	-4.25	-3.15	-5.28	-1.04
oag	-12.25	-12.29	-5.43	-7.06	22.37	20.22	12.37	-13.25
mng	27.29	27.41	33.05	44.38	23.96	22.64	30.55	10.27
elc	-3.67	-3.68	-3.25	-2.40	-1.39	-0.49	-4.85	6.01
cns	0.06	0.06	0.07	0.08	0.04	0.04	0.06	0.01
oman	4.83	4.84	4.43	0.24	-0.98	-4.21	2.45	1.51
ppr	-3.55	-3.57	-3.01	-9.58	-5.28	-4.24	-7.58	3.06
rpp	-11.07	-11.11	-10.32	-8.81	2.40	6.20	-8.94	-5.26
chem	-9.09	-9.12	-9.30	-27.12	1.10	-4.28	-9.41	-6.62
ind	-11.64	-11.71	-13.22	-8.28	-3.05	-1.81	9.90	10.64
mtl	-9.37	-9.42	-10.86	-7.62	-2.93	-2.16	-13.40	0.99
wrt	0.57	0.59	0.27	1.00	0.35	0.24	0.57	-0.04
tran	-5.62	-5.63	-6.83	-3.87	-2.87	-2.18	-7.64	-3.00
serv	1.74	1.75	1.52	2.22	1.01	0.74	1.70	0.65
gs	0.10	0.10	0.06	0.07	0.14	0.11	0.08	0.02

*Note: All values measured in percentage change from reference case scenario.*

## **Conclusion**

The Canadian government has committed to reducing greenhouse gas emissions by 20 percent below 2006 levels by 2020. Given its fast rate of projected population growth, economic growth, and growth in energy exports, high carbon prices will likely be required to achieve such targets. Concern has naturally been raised that these carbon prices could harm the competitiveness of Canadian industry, and especially of energy-intensive manufacturers.

The analysis in this paper reinforces the conclusion reached in other papers and by the public that aggressive Canadian reduction of greenhouse gas emissions – without similar action by other countries – could impinge on the international competitiveness of Canada’s most energy-intensive sectors. In particular, the analysis highlights the fossil fuel extraction and processing sectors, the industrial minerals sector, and the metal and industrial chemical manufacturing sectors as those most likely to lose market share to foreign competitors following Canadian implementation of a carbon price. While these sectors are responsible for a fairly small share of overall economic output and employment, significant loss of international competitiveness in these sectors may still be politically unpalatable.

The analysis does suggest that design options are available which could significantly mitigate the competitiveness impacts associated with carbon pricing. In particular, output-based rebating of emission permit or tax revenue, which eliminates any incentive to curtail production as a way to reduce emissions, appears likely to significantly reduce competitiveness impacts of carbon pricing. While this design option does introduce an additional distortion into the permit market, significantly increasing the price of carbon necessary for a given level of emission reductions, it

does not appear likely to damage welfare or economic output considerably. Additionally, output-based rebating, which is essentially the policy proposed by the Canadian government, is unlikely to conflict with international trade rules.

Other options can also reduce competitiveness impacts of carbon pricing, although not without significant tradeoffs. Sector exemptions from the policy – aimed at the sectors most likely to suffer loss of market share to foreign firms following carbon pricing – should reduce or even eliminate competitiveness impacts in exempted sectors, but concentrate the burden of carbon pricing on a smaller set of sectors, thus amplifying the impacts on these sectors, and weakening the economy as a whole.

Border tax adjustments also appear likely to significantly reduce the competitiveness impacts associated with climate policy, but not without considerable tradeoffs. Import tariffs, which raise the price of consumption in Canada, significantly reduce welfare and economic output. Export rebates appear more likely to improve welfare and economic growth in Canada; however, political and legal hurdles to both policies are likely to be large. In particular, it is unclear whether border tax adjustments are compatible with international trade law. Even if they were, adoption of border taxes could spur retaliatory measures that are damaging to Canadian competitiveness.

Finally, the analysis suggests that revenue recycling strategies, which use revenue raised from carbon pricing to cut labour and capital tax rates, are unlikely to preserve the international competitiveness of energy-intensive Canadian manufacturing sectors. These sectors tend to have lower capital and labour requirements than other sectors relative to energy consumption, such

that benefits of cuts in taxation of these factors are outweighed by increases in price from carbon pricing. In contrast, less energy-intensive sectors may have their international competitiveness improved by this type of revenue recycling strategy. Importantly, however, revenue recycling – in particular to cut capital taxation – can significantly reduce the overall economic cost of climate policy. This finding is consistent with other studies.

There are several important limitations of this analysis. Most importantly, a single-country model is used, and unilateral Canadian implementation of climate policy is assumed. In reality, although a fully global climate agreement is unlikely in the near future, some countries (e.g., European countries) have already implemented climate policies, and others are likely to follow in the near future. A fully global model would allow exploration of the impacts of several alternative scenarios surrounding international climate policy implementation, and the impacts on Canadian competitiveness. It is likely that if other countries – in particular the US – were to implement climate policy at the same time as Canada, competitiveness impacts shown here would be much reduced.

Another limitation of the approach adopted here is the absence of incorporation of endogenous technical change into the model, which is increasingly being explored in general equilibrium models. It is unclear what effect this omission has on the findings offered here. Additionally, the model assumes perfect competition in all markets, which may not be appropriate, given the small number of firms in some sectors. Other analysis suggests that changing this assumption can affect the conclusions about international competitiveness (Babiker 2005).

Despite the limitations, the results suggest that it is possible for Canada to implement climate

policy unilaterally with fairly minimal losses to international competitiveness, by adopting carbon pricing policies with appropriate design options. In particular, output-based rebating of emission permits, which is the effectively government’s current policy approach, appears likely to minimize competitiveness losses without contravening international trade rules. While this may not be the most efficient approach – using the revenues to cut existing taxes appears more likely to maintain economic output and welfare – it may be appropriate in the face of public hostility to competitiveness losses, and given Canada’s uncertainty about carbon pricing policies that will be implemented by its trading partners.

## Appendix

### *Model parameters*

Parameter values to populate the model are drawn from a variety of sources. For key parameters relating to substitution between capital and energy and between different energy types in both household consumption and industry production, values are drawn from pseudo-data generated by a hybrid Canadian energy economy model, as reported in Bataille et al. (2006). These values are generally similar to values assumed in applications of CGE models (Babiker 2005; Böhringer and Rutherford 1997). The elasticity of substitution between consumption and leisure is calibrated to give an uncompensated labour supply elasticity of 0.2, which is close to the average of the wide range of published estimates of this parameter (Evers, de Mooij, Ruud A., van Vuuren, Daniel J. 2005). Import and export elasticities are drawn from Wirjanto (1999).

**Table 4: Model parameters**

<i>Parameter</i>	<i>Description</i>	<i>Value</i>
<i>Household utility function elasticities</i>		
$\sigma_t$	Elasticity of intertemporal substitution	0.5
$\sigma_{cl}$	Elasticity of substitution between consumption and leisure	0.2
$\sigma_{eg}$	Elasticity of substitution between electricity and natural gas in residential consumption	0.65
$\sigma_{ht}$	Elasticity of substitution between gas-electricity aggregate and petroleum products	0.3
$\sigma_{ne}$	Elasticity of substitution between non-energy goods	0.25

$\sigma_{ne}$	Elasticity of substitution between non-energy aggregate and energy aggregate	0.15
<i>Production function elasticities</i>		
$\sigma_{s,j}$	Elasticity of substitution between energy-value-added aggregate and material aggregate	0
$\sigma_{va,j}$	Elasticity of substitution between energy and value added aggregate	0.27 – 1.8
$\sigma_{ef,j}$	Elasticity of substitution between electricity and fuels	0.2 – 1.1
$\sigma_{cgl,j}$	Elasticity of substitution between coal and other fuels	0.3 – 0.75
$\sigma_{gl,j}$	Elasticity of substitution between natural gas and petroleum products	0.1 – 2.5
$\sigma_{kl,j}$	Elasticity of substitution between capital and labour	1.1
$\sigma_{in,j}$	Elasticity of substitution between intermediate non-energy material inputs	0.05 – 0.5
<i>Trade elasticities</i>		
$\sigma_{hf,i}$	Elasticity of substitution between home and foreign goods (Armington elasticity)	0.9 – 3.5
$\sigma_{dx,i}$	Elasticity of transformation between domestic and export markets	0.9 – 3.5
<i>Dynamic parameters</i>		
$\phi$	Interest rate	0.039
$\delta$	Depreciation rate	0.05

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