C.D. Howe Institute
COMMENTARY

ECONOMIC GROWTH AND INNOVATION

Pricing Greenhouse Gas Emissions:

The Impact on Canada's Competitiveness

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In this issue...

There is a growing consensus that if serious action is to be taken to reduce greenhouse gas emissions in Canada, a price must be applied to emissions. But how would Canada's climate policy coexist with the rest of the world? And how would domestic industry be affected?

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THE STUDY IN BRIEF

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There is a growing consensus that, if serious action is to be taken to reduce greenhouse gas (GHG) emissions in Canada, a price must be applied to those emissions. There are, however, challenges associated with the political acceptability of carbon pricing. If Canada implements a carbon price on its own, there are worries that Canadian factories will relocate to other countries to avoid the regulation. Even if other countries act in concert with Canada to price carbon, the effects will be uneven across sectors, and lobbying efforts by relatively more-affected sectors might threaten the political viability of the policy.

This study looks at a number of scenarios of how Canada's climate policy might coexist with the rest of the world, how certain sectors are likely to be affected by carbon pricing and what governments can do about it. Overall, we find that competitiveness impacts associated with climate change policy in Canada are likely to be relatively small for most sectors of the economy, with the exception of fossil fuel extraction industries.

A related concern is that measures Canada might take to reduce GHG emissions would be partly offset by the relocation of Canadian industries to countries that lack tough climate change policies – an effect known as emissions "leakage." Such leakage, however, would be relatively small: for every 5 megatonnes of CO_2 that is reduced by Canadian industry, only 1 megatonne would be leaked abroad. Leakage would be primarily to the United States, rather than to developing countries. Thus, Canada can move forward with tough climate policy without the cooperation of the developing world and with little concern about carbon-intensive production moving there.

Despite the finding that the overall competitiveness and leakage impacts associated with climate change policy in Canada are likely to be small, they remain an important concern for policymakers. The study explores several mechanisms, such as border tax adjustments, that could be used to mitigate these effects, and finds that while such measures can be successful at reducing competitiveness impacts, such protection is likely costly to both the wider economy and the environment, and ill prepare Canada for a long-term future with significant carbon pricing. Policymakers must be cautious in considering these measures.

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Most economists believe that putting a price on carbon emissions, typically through some form of cap-and-trade system or a carbon tax, is an effective and low-cost way to reduce greenhouse gas (GHG) emissions.[1] Given the global nature of the climate change threat and the open nature of Canada's economy, an economically optimal response would be a globally integrated carbon-pricing system.

While governments have not been quick to implement carbon pricing, and certainly have not done so on a global level, several US and Canadian jurisdictions have followed the European Union in setting a cap or price on carbon emissions. This raises the prospect of a fragmented patchwork of carbon-pricing policies. If Canada were to price carbon without cooperating with other industrialized countries, could this hurt the competitiveness of some Canadian industries and cause jobs and economic output to move abroad? Indeed, would industries that emit large amounts of GHGs simply shift to countries where emissions are neither priced nor regulated, causing carbon "leakage" and partially offsetting whatever Canada does to reduce its own GHG emissions?

To date, only a few Canadian studies have looked at competitiveness concerns with respect to carbon pricing and the policy tools that might be used to alleviate such concerns (see, for example, Wigle 2001), with inconclusive results. Nevertheless, elements of the domestic debate over climate change policy seem to assume that there are significant competitiveness issues, and government policy has been adjusted to reflect this concern.[2] Is policy to alleviate the effects on competitiveness, such as border tax adjustments or exemptions from cap-and-trade limits, warranted and in what situations?

In this *Commentary*, we show the competitiveness effects of a possible carbon-price path from 2010 through 2020 that meets the goals of announced government policy: a 20 percent reduction in GHG emissions by 2020 from the level that prevailed in 2006. We find that:

- competitiveness concerns for the entire economy and fears of substantial emissions leakage are largely unfounded;
- carbon pricing on this scale would have a significant effect on competitiveness only in a handful of energy and otherwise carbon-intensive industries, as well as those associated with fossil fuel energy production and processing; and
- carbon leakage would be greatest if Canada were to impose significantly higher carbon pricing than the United States, while leakage to developing countries would be negligible.

Carbon pricing, however, faces serious challenges, since its effect would be uneven across sectors and lobbying efforts by relatively exposed sectors could threaten the political viability of the policy. Border tax adjustments, free allocations of nonsalable permits (effectively, emissions exemptions), or some other competitiveness policy might be necessary to enhance the political survivability of carbon pricing, but we also find that border tax adjustments would slightly reduce the effectiveness of a carbon-pricing policy, face technical and legal challenges, and ill prepare Canada for a long-term future with significant carbon pricing. Policymakers thus must be careful in deciding whether the distortionary effects we measure of policies to support internationally competitive industries are worth the political benefit of assisting sectors disproportionately harmed by carbon pricing.
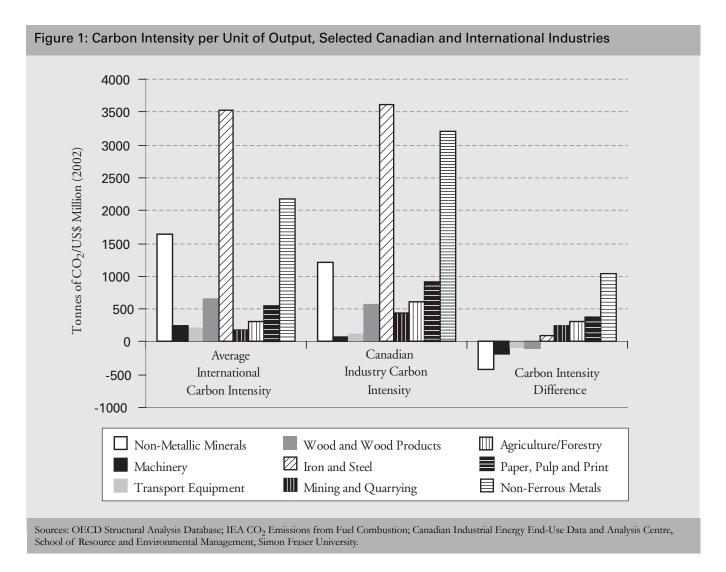
GHG Emissions Policy and Canadian Industry

The effect of carbon pricing on Canadian industrial competitiveness and global GHG emissions would depend on whether Canada imposes carbon pricing

Figure 1: Carbon Intensity per Unit of Output, Selected Canadian and International Industries

Legend:
- □ Non-Metallic Minerals
- ▨ Wood and Wood Products
- ▥ Agriculture/Forestry
- ■ Machinery
- ▧ Iron and Steel
- ▤ Paper, Pulp and Print
- ▨ Transport Equipment
- ▥ Mining and Quarrying
- ▤ Non-Ferrous Metals

Sources: OECD Structural Analysis Database; IEA CO_2 Emissions from Fuel Combustion; Canadian Industrial Energy End-Use Data and Analysis Centre, School of Resource and Environmental Management, Simon Fraser University.
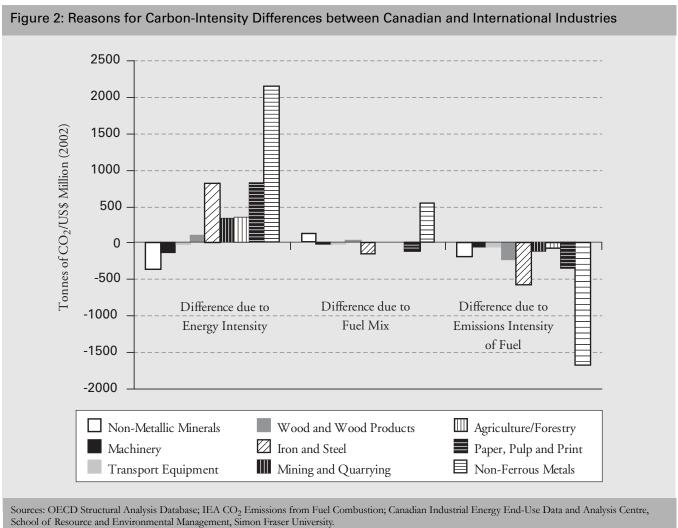
unilaterally or in conjunction with its trading partners. In an ideal world, Canada would act along with much of the rest of the world in placing a common price on carbon emissions. With a common global carbon price, GHG emissions would become a common cost of doing business, and industries that reduce this cost the most would have an advantage relative to industries that emit more emissions for the same amount of output. In this case, the competitiveness effect would depend on the carbon intensity of trade-exposed Canadian industries relative to their competitors.

The GHG Intensity of Canadian Industries Relative to International Competitors

Between 1990 and 2006, total Canadian GHG emissions rose from 592 megatonnes to 721 megatonnes, and industry consistently accounted for about 40 percent of all Canadian emissions (excluding those from electricity generation). Over the same period, aggregate emissions of Canadian industry per dollar of value added were marginally lower than the average emissions of Canada's major trading partners (574 tonnes versus 602 tonnes per US$1 million – see Figure 1).[3] Most Canadian manufacturing industries are slightly less carbon intensive than their international competitors, whereas most energy-intensive industries tend to be more carbon intensive.

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3   By "major trading partners," we mean the other G7 countries (United States, United Kingdom, Italy, Germany, France, and Japan), as well as South Korea and Mexico.

Figure 2: Reasons for Carbon-Intensity Differences between Canadian and International Industries

Sources: OECD Structural Analysis Database; IEA CO_2 Emissions from Fuel Combustion; Canadian Industrial Energy End-Use Data and Analysis Centre, School of Resource and Environmental Management, Simon Fraser University.

Differences in industrial emissions per output across countries are due to: (i) differences in energy per unit of output; (ii) differences in the GHG intensity of the energy supply mix;[4] or (iii) differences in the GHG intensity of individual energy types, particularly electricity production (see Figure 2).[5] On average, Canadian industries have an advantage over their international competitors with respect to carbon intensity per unit of energy because of their wide use of relatively low GHG-emitting electricity from hydro and nuclear power sources (see Figure 2, column 3). Thus, the introduction of a carbon price comparable across countries would result in a cost advantage for non-energy-intensive industries, while having significant negative effects on Canada's relatively carbon-intensive extractive industries. If Canadian industries were to face a relatively higher carbon price in a world with patchwork carbon pricing, these effects could be even more pronounced.
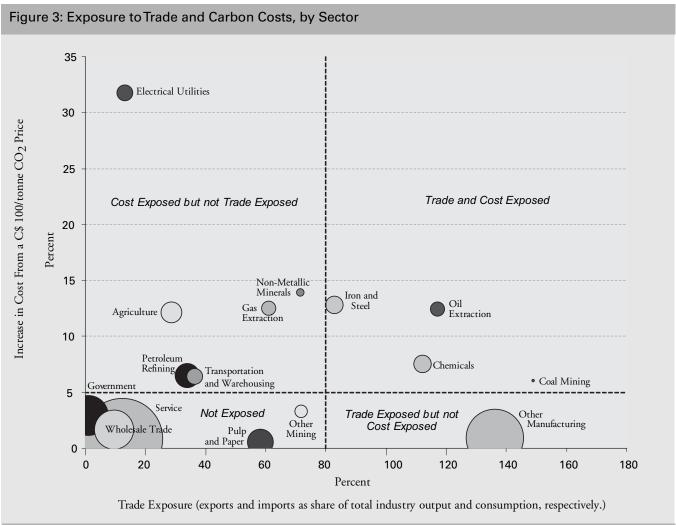
The Trade Basis of Canadian Competitiveness

Besides relative GHG intensity per unit of product, another way of understanding how the competitiveness of Canadian companies would be affected by a carbon price is to look at their degree of trade

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4   For example, coal emits about 0.09 tonnes of CO_2e per gigajoule of energy produced, while natural gas emits about 0.05 tonnes of CO_2e per gigajoule of energy.

5   Bataille et al. (2007), expanding on Ang (2005), provide a method for comparing energy or emissions across countries; see the appendix for a discussion of the decomposition technique.

Figure 3: Exposure to Trade and Carbon Costs, by Sector

Note: The horizontal axis shows the sum of (i) sector exports as a share of gross output and (ii) imports as a share of consumption. The vertical axis shows the increase in costs associated with a $100/tonne CO_2e price – which is roughly consistent with Canada's goal of achieving a reduction of 20 percent from today's level by 2020 – applied on all emissions. The size of the circles indicates the relative gross output of the sector relative to that of the entire economy.

Source: Rivers 2008.

exposure, measured by the combined share of imports in domestic consumption and the fraction of domestic production that is exported. Sectors most likely to see an impact on their competitiveness as a result of carbon pricing are those that are both greenhouse gas intensive and trade exposed – particularly the iron and steel, chemical, and gas, oil, and coal extraction industries (those in the top right-hand quadrant of Figure 3). If Canada were to impose carbon pricing unilaterally, these sectors would be most likely to face reduced international competitiveness. At the same time, the effects of

carbon pricing on competitiveness would be unevenly allocated across the country since, although these industries account for only a fairly small proportion of overall economic output compared with other manufacturing and service industries, they are generally located in western Canada. Moreover, competitiveness could be a concern whether carbon pricing were applied globally or regionally. With global carbon pricing, Canada's extractive sectors might be placed at a relative disadvantage because of their high carbon intensity relative to their competitors.

Modelling the Effects of Carbon Pricing on Competitiveness

In the decomposition and trade exposure analysis, there is no recognition of the sensitivity of demand for Canada's exports to increases in carbon costs, and the capacity for Canadian industry to reduce its GHG intensity. Individual businesses and sectors as a whole can change their production processes to be less GHG intensive, and firms and consumers can switch to less GHG-intensive products. How, then, would the competitiveness of Canadian industry look if a carbon-price schedule were implemented that met Canada's announced emissions goal of a 20 percent reduction from 2006 levels by 2020?[6]

To explore this question, we use two modelling tools. The first is the Canadian Integrated Modelling System (CIMS) hybrid technology simulation model (see Jaccard et al. 2003; Bataille et al. 2006), which we use to isolate the pricing path necessary to hit the announced target and to explore the basic effects of differing scenarios of international climate policy cooperation. We then use the Dynamic Computable General Equilibrium Emissions Model (DGEEM, see Rivers 2008; Rivers and Sawyer 2008), using the expected carbon prices and changes in the economy estimated by CIMS, to explore the detailed macroeconomic effects on trade, economic structure, capital, and labour markets of the most extreme scenario, whereby Canada acts alone.

The potential effects on competitiveness of Canadian climate policy depend on the policies implemented in other countries. Here, we compare three different scenarios, given a Canadian carbon-price schedule that rises from $15/tonne CO_2e in 2010 to $115/tonne CO_2e by 2020 (a path sufficient to reach Canada's announced target):

- all countries implement a carbon-pricing scheme similar to Canada's;
- the member countries of the Organisation for Economic Co-operation and Development (OECD) implement a carbon-pricing scheme similar to Canada's but other countries do not; and
- only Canada implements a carbon-pricing policy.

These scenarios are meant as bookends, useful for exploring the sensitivity of the models to different assumptions. The method used to simulate the three states of the world with the common carbon-pricing schedule is twofold. First, we simulate the carbon-pricing schedule in CIMS as the equivalent of an absolute cap-and-trade system with auctioned permits, similar in nature to a carbon tax.[7] Second, we examine the different scenarios for international climate policy cooperation by changing the degree to which domestic production of goods can be substituted for internationally traded goods. In the scenario where Canada acts alone in pricing carbon, we set this substitution at the largest it can be. In the scenario where only the OECD countries cooperate, we set this substitution at half that amount; in the scenario where the globe cooperates, we set the substitution at one-quarter of the largest possible amount. The remaining quarter represents a judgmental value of the basic demand for the goods and services in question, as opposed to potential competitiveness effects from differential costs and prices.

Table 1 shows estimated Canadian GHG emissions in 2020 by sector and for the country as a whole under a business-as-usual case and the carbon-pricing path in the three scenarios. In every

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6   In this analysis all comparisons are to 2005 emissions, as this was the GHG Inventory that was available when the analysis was done. Canada's official total emissions as of late 2008 were 734 Mt in 2005, and 721 Mt in 2006.

7   An absolute cap-and-trade system with auctioned permits is an emissions limitation policy that operates as follows. At the beginning of a given period, the government issues a limited number of emissions permits, set to match its emissions target in a given period. These are issued by auction to the highest bidder. At the end of each period, all emitters must remit sufficient permits to cover all their emissions. Between the auction and the end of the period, all permits are freely tradable. A simpler policy instrument is an upstream carbon tax, whereby a charge is levied on all emissions. Either instrument can be imposed at the point of emission – at least, in the case of large sources of emissions – or, in the case of fossil fuels, at upstream collection and transmission points in the fossil fuel importation, extraction, and processing system. Roughly 80 percent of Canadian emissions are reasonably amenable to carbon pricing through either a cap-and-trade system or a carbon tax. Other emissions sources, such as landfill waste gas, agricultural emissions, or venting in the upstream oil and gas industry, might require complementary policies, such as direct regulation that mimics the carbon price or a mechanism to issue offset credits.

Table 1: Emissions under Various Scenarios, 2020

	Scenario						
Sector	Business as Usual (megatonnes of CO_2)	Canada Acts Alone	(megatonnes of CO_2)	OECD Cooperates	(megatonnes of CO_2)	Globe Cooperates	(megatonnes of CO_2)
		% change		% change		% change	
Household	39.6	-49	-19.3	-49	-19.2	-49	-19.2
Commercial and institutional	40.6	-32	-13.0	-32	-13.0	-32	-13.0
Landfill waste	30.5	-84	-25.7	-84	-25.7	-84	-25.7
Electricity generation	112.7	-8	-9.6	-7	-8.3	-7	-7.9
Personal transportation	117.7	-20	-23.8	-20	-23.8	-20	-23.8
Freight transportation	128.7	-42	-54.3	-41	-53.2	-41	-52.8
Ethanol	0.0	1,799	0.3	1,793	0.3	1,796	0.3
Biodiesel	0.2	1,063	1.6	1,103	1.7	1,120	1.7
Energy-intensive industry							
Chemical products	12.6	-51	-6.5	-42	-5.3	-40	-5.0
Industrial minerals	19.6	-60	-11.7	-49	-9.7	-44	-8.7
Iron and steel	14.1	-7	-0.9	-7	-1.0	-7	-1.0
Metal smelting	8.6	-8	-0.7	-7	-0.6	-6	-0.5
Mineral mining	5.3	-24	-1.3	-20	-1.1	-19	-1.0
Paper manufacturing	3.8	-11	-0.4	-8	-0.3	-6	-0.2
Other manufacturing	26.3	-42	-11.1	-40	-10.6	-40	-10.5
Petroleum refining	24.3	-37	-8.9	-36	-8.8	-36	-8.8
Petroleum crude extraction	158.2	-51 to -54	-81 to -85	-51 to -53	-80 to -84	-51 to -53	-80 to -83
Natural gas extraction	55.5	-27 to -35	-15 to -19	-27 to -34	-15 to -19	-27 to -34	-15 to -19
Coal mining	2.5	4	0.1	5	0.1	6	0.1
Total industry	**304.1**		**-136.8**		**-131.1**		**-128.8**
Total	**800.9**		**-289.4**		**-281.0**		**-277.9**

Note: Emissions for this analysis do not include those from agriculture, halocarbons, solvents (nitric and adipic acid) and land use change. For petroleum and natural gas extraction, the first estimate is with economic rents, the second is with no economic rents.

Source: Authors' calculations from CIMS.

scenario, the greatest emissions reductions come in the following sectors:

- petroleum crude extraction (a reduction of about 80 to 85 megatonnes), mainly through reductions in output, reduced well venting, and the use of carbon capture and storage at new oil sands facilities;
- freight transportation (a reduction of about 53 megatonnes), mainly through efficiency (hybridization, resizing of vehicles), the use of alternative fuels, and mode switching;
- a reduction in landfill waste gas (of about 26 megatonnes), through capping, flaring, and cogeneration, as appropriate;

- personal transportation (a reduction of about 24 megatonnes), as with freight transportation, mainly through efficiency (hybridization, resizing of vehicles), alternative fuels, and mode switching;
- residential and commercial buildings (a reduction of about 32 megatonnes), mainly through insulation and furnace efficiency, the use of ground and air source heat pumps, and fuel-switching to electricity; and
- natural gas extraction and processing (a reduction of about 15 to 20 megatonnes), mainly through reductions in output and the capture and storage of formation CO_2.

Table 2: Projected Changes in Physical Output of Energy-Intensive Sectors, 2020

	Scenario		
	Canada Acts Alone	OECD Cooperates	Globe Cooperates
Industry		*(% change)*	
Chemical products (tonnes)	-10	-3	-2
Industrial minerals (tonnes)	-50	-27	-14
Iron and steel (tonnes)	0	0	0
Metal smelting (tonnes)	-3	-2	-1
Mineral mining (tonnes)	-1	-1	0
Paper manufacturing (tonnes)	-9	-4	-2
Other manufacturing (2005 $ GDP)	-4	-1	-1
Petroleum refining (cubic metres)	-28	-28	-27
Petroleum crude extraction (barrels per day)	0 to -8	0 to -6	0 to -5
Natural gas extraction (cubic metres)	0 to -16	0 to -15	0 to -14

Note: For petroleum and natural gas extraction, the first estimate is with economic rents, the second is with no economic rents.

Source: Authors' calculations from CIMS.

In most sectors, the results do not change by more than 1 percent, or by 0.1 megatonnes, amongst any of the scenarios of international cooperation. The most obvious exceptions are the chemical products, industrial minerals (cement and lime production), mineral mining, pulp and paper, and other manufacturing sectors. In our analysis, chemical products, especially industrial minerals, are affected the most because of their fixed-process GHG emissions, high energy intensity, and the propensity of domestic and foreign demand for domestically produced chemicals, cement, and lime to be substitutable for production from outside Canada. Planned carbon policies in Canada and Europe would exempt fixed-process emissions, such as calcination in the making of lime, which would greatly reduce the effect of an emissions reduction policy on the industrial minerals sector. Other proposed policies, including bills before the US Congress and the Western Climate Initiative, incorporate fixed-process emissions, but compensating border adjustments are anticipated.

In Table 2, we show estimated changes in physical output by industrial sector in 2020 under the business-as-usual case and the common carbon-pricing schedule in the three scenarios, estimated using the CIMS model. Although most sectors would be largely unaffected, several energy-intensive

sectors likely would face increased prices and, therefore, reduced demand for their products. In particular, the oil and gas, chemical products, industrial minerals, metal smelting, and pulp and paper manufacturing sectors could face declines if Canada were to implement an aggressive carbon price unilaterally.

By far the most affected sector if Canada acted alone would be industrial minerals (cement and lime production). In our simulations, physical output falls 50 percent if Canada acts alone, 27 percent with OECD cooperation, and 14 percent with full global cooperation. In contrast, the petroleum refining and iron and steel industries see little change under any of the scenarios, suggesting that these industries are most responsive to domestic policy. In our model simulations, we assume that both noncombustion (process) emissions and combustion emissions are affected by the policy. Again, however, the exemption of fixed-process emissions from proposed Canadian and European carbon reduction policies would greatly reduce their overall effects.

The effects on the petroleum crude and natural gas sectors are sensitive to whether or not the cost increases from carbon abatement are absorbed in provincial royalties and firm profits or passed on to consumers. Both sectors differ somewhat from the

Table 3: Change in Exports, Imports, and Gross Output under Business-as-Usual and Canada-Acts-Alone Scenarios, 2020

Industry	Exports Business as Usual (2000 $ billions)	Canada Acts Alone (2000 $ billions)	Change (%)	Imports Business as Usual (2000 $ billions)	Canada Acts Alone (2000 $ billions)	Change (%)	Gross Output Business as Usual (2000 $ billions)	Canada Acts Alone (2000 $ billions)	Change (%)
Agriculture	15.7	15.8	0	8.1	8.3	3	76.3	77.8	2
Mining	14.1	12.7	-10	8.0	7.4	-8	32.2	29.3	-9
Coal mining	2.1	1.3	-39	2.1	1.5	-27	2.5	1.5	-37
Crude oil extraction	37.5	22.1	-41	30.7	26.8	-13	45.7	28.7	-3
Natural gas extraction & production	18.0	12.0	-33	0.2	0.2	-22	33.0	23.5	-29
Other manufacturing	436.4	466.8	7	464.4	454.2	-2	614.1	643.9	5
Paper manufacturing	12.8	12.2	-5	3.5	3.6	4	26.5	26.0	-2
Metals production	42.1	37.6	-11	28.2	29.3	4	85.7	82.2	-4
Petroleum refining	11.7	8.9	-24	6.2	6.0	-4	48.8	42.5	-13
Services	69.4	68.8	-1	74.3	71.4	-4	1,110.4	1,069.6	-4
Cement	6.8	6.1	-10	8.7	8.9	2	19.8	18.7	-5
Chemicals	31.1	25.9	-17	41.5	41.7	0	52.3	47.4	-9
Construction	NA	NA	NA	NA	NA	NA	214.3	209.4	-2
Transportation	41.6	38.2	-8	13.7	14.0	2	163.6	159.5	-3
Retailing & wholesaling	25.5	25.2	-1	1.2	1.1	-5	271.0	261.6	-3
Electricity utilities	6.0	5.5	-8	0.7	0.8	9	40.2	41.2	3
Government services	2.3	2.5	9	2.5	2.5	3	369.4	385.8	4

Source: Authors' calculations from CIMS and DGEEM. Data sources in Appendix.

other traded sectors in that the market price for these commodities is generally greater than the marginal cost of producing them – the difference is known as "economic rents," in the form of provincial royalties or profits that are higher than those in the rest of the economy. In both sectors, the provinces (which own the raw resources) and the industry (which provides the extraction capacity) implicitly negotiate the division of these structural profits between them. In an industry without rents, the addition of carbon abatement costs normally would drive up the consumer price and reduce demand. In these two sectors, however, the rents may be sufficient to absorb the costs of carbon abatement.

Since the CIMS model focuses on the most energy- and emissions-intensive sectors of the economy, it contains a high level of detail on technology, investment, energy use and emissions for those sectors, but less detail on the broader economic implications of climate policy and on the other sectors of the economy. Thus, to see the effects

on the wider economy of the carbon-pricing trajectory we described above, we look at the effects on exports, imports, and gross output if Canada were to act alone, using a computable general equilibrium model whose production functions have been calibrated to CIMS' responses to carbon pricing (see Table 3).

We find that coal, oil, and gas exports and imports would drop significantly – although, since we model these industries as perfectly competitive, the inclusion of more realistic rents might change these results. Exports would also decline in heavy manufacturing sectors – petroleum refining, cement production, chemical production, and primary metal manufacturing, while manufacturing imports would fall as a result of reduced overall economic activity. We also predict that Canadian gross domestic product (GDP) would decline by 1.5 to 2 percent by 2020 relative to a baseline with no carbon pricing if Canada implements a tougher climate policy than its trading partners and if all

trading sectors face a competitive market environment.

The results from both the CIMS model and the general equilibrium analysis are generally consistent. Both models suggest three main outcomes. First, production in the energy extraction sectors is likely to decline as a result of carbon pricing. This result is not necessarily related to international competitiveness; since international carbon-pricing policies are likely to reduce demand for fossil fuels around the world, it makes sense that production of these products would also decline. Second, the competitiveness of some energy-intensive manufacturing sectors is likely to be affected as a result of aggressive carbon pricing in Canada. In particular, the models suggest that the chemical, cement, mining, and metal manufacturing sectors could be exposed to increased competition from abroad in the face of unilateral carbon pricing. Third, the overall effect of a tough carbon-pricing policy would be a significant restructuring of the economy, with a long-term reorientation from capital- and energy-intensive sectors to more labour-intensive manufacturing and services sectors. This result is consistent with the many other studies of carbon pricing that have been conducted internationally.[8]

Measures to Protect Canadian Industry

Since certain sectors would see reduced national and international demand for their products if Canada were to impose tough carbon pricing unilaterally, there could be pressure to mitigate these losses through trade measures. Among the measures that have been proposed are border tax adjustments in the form of tariffs on imports to reduce the gain in domestic market share by foreign companies, and export rebates to reduce the loss of foreign market share by Canadian companies. Combining these two options would create a destination-based tax whereby the only GHG pricing applied on a given product would be that imposed by the consuming country. Frequently, this type of border tax

adjustment is discussed with respect to sub-global carbon-pricing schemes (see, for example, Hoel 1996; Demailly and Quirion 2005; and Courchene and Allan 2008). Indeed, such a system is already in place for value-added taxes such as Canada's goods and services tax, which allows for rebates on exports and applies the domestic value-added tax to imports.

A border tax adjustment scheme would allow Canada to impose carbon pricing unilaterally, while possibly addressing the competitiveness implications. Under such a scheme, Canadian exporters would receive rebates proportional to the total carbon embedded in their products, while importers would be required to pay import duties proportional to embedded carbon. Such a scheme, in theory, would prevent the application of a Canadian carbon-pricing policy from influencing decisions about from where to purchase products, therefore alleviating concerns about leakage and competitiveness.

Border tax adjustments have been criticized, however, as being infeasible due to both the complexity of calculating the amount of carbon embedded in a product and the likelihood that such taxes might not comply with World Trade Organization (WTO) rules. As Pauwelyn (2007) notes, carbon tariffs applied unevenly across countries based on the carbon content of each country's production process might violate most-favoured-nation clauses, anti-discriminatory rules, or rules concerning maximum allowable tariff levels. On the other hand, border tax adjustment policies that applied an equal carbon price to both foreign and domestic firms and did not discriminate by country might be WTO compliant and practical to implement if their calculation were based solely on Canadian or internationally consistent emissions data (Ismer and Neuhoff 2004).

Using the computable general equilibrium model described earlier to understand the implications of carbon tariffs and export subsidies on key economic

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8   Wigle (2001, section 2.1) provides a summary of studies assessing the effect on GDP of climate policy of varying toughness. A survey of Canadian studies from the 1990s (Howatson and Campfens 1997) that analyzed the stabilization of emissions at 1990 levels in 2010, with no global trade in permits, predicted the cost to be between 0.5 and 1.8 percent of GDP. A special issue of *Energy Journal* ("The Costs of the Kyoto Protocol: A Multi-Model Evaluation," May 1999) showed the effects of meeting the more stringent target of the Kyoto Protocol to be between 0.6 and 2.2 percent of Canada's GDP by 2010; if the trading of permits were allowed, the nominal GDP cost would be reduced by between 0.6 and 1.0 percent.

Table 4: Effect of Competitiveness Mechanisms, 2020

	No Adjustments	Import Tariff	Export Rebate
	(percentage change)		
Gross domestic product	-1.75	-1.83	-0.62
Gross output	-2.03	-2.05	-1.80
Total trade	-0.69	-0.97	-0.63
GHG emissions compared with business-as-usual scenario	-33.24	-33.11	-29.09

Source: Authors' calculations from CIMS and DGEEM. Data sources in Appendix.

variables, we find that tariffs on imports would be detrimental to overall economic output, volume of trade, and would diminish the GHG reductions relative to an absence of border tax adjustments (see Table 4).[9] The application of rebates on exports, on the other hand, could reduce slightly the economic cost of the policy, but it would also weaken its environmental effectiveness by around 4 percentage points from what would be obtained from a pure carbon price.

The theoretical economic rationale for border tax adjustments in a world with sub-global carbon-pricing policy is reasonably clear, but there would be significant potential legal and technical constraints. Moreover, given the significant momentum toward reducing trade frictions over the past half-century, the political appetite for such measures might be limited. Finally, as the modelling here suggests, there are economic tradeoffs associated with border tax adjustments. The issue of border tax adjustments is certainly worthy of additional study, but they are unlikely to resolve the competitiveness debate. And it remains an open question whether, from the perspective of the long-term health of the entire Canadian economy in a carbon-constrained world,

the effects on competitiveness would be serious enough to merit their use.

Other Measures to Protect Industries

There are other ways to protect industries from carbon pricing, although we do not model them here. Under a cap-and-trade system, selected industries could be allocated permits to emit GHGs for free or at a reduced rate on the grounds of competitiveness (Morgenstern 2007), with the condition they cannot be resold. However, the initial allocation of credits, if handed out to industries in an arbitrary fashion, can affect the efficiency and equity of a carbon-pricing scheme while perhaps not even achieving the goal of aiding competitiveness. Given a cost for carbon at \$100/tonne CO_2e, a market for all emissions related to industrial emissions would involve the creation and distribution of assets worth around \$20 billion if the cap were set at 200 megatonnes.

The European Commission has proposed providing all carbon credits for free to industries that are both highly trade exposed and likely to see significant cost increases as a result of carbon pricing

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9   In the import-tariffs scenario, the tariff is set by commodity so that imports are prevented from capturing more than 10 percent of the domestic market relative to the business-as-usual scenario.

(the industries in the top right-hand corner of Figure 3), while industries with low trade exposure and little expected increase in costs from carbon pricing would have to purchase carbon permits from governments (Reinaud 2008). Temporary free allocation of emissions permits based on universally applied rules of expected cost and trade exposure could be studied further to determine their effect on emissions and the economy.

The Effect on Global Emissions Levels

That Canadian emissions of GHGs would fall dramatically (on the order of one-third) as a result of tough carbon pricing is no surprise. But that is not the end of the story if Canada acts alone to reduce emissions. Dealing with global climate change means not just reducing Canadian emissions, but world emissions. The emissions embedded in goods produced by Canada's trading partners for consumption in Canada must also be considered when examining the total carbon footprint of Canadian consumption, as must the emissions attributable to Canadian goods that are exported and consumed elsewhere. If goods produced in Canada for export are manufactured with lower GHG emissions than are foreign-produced goods, then scaling back production only in Canada might reduce overall emissions by less than anticipated. Recent economic modelling suggests that around one-quarter of the reduction in Canadian emissions from energy-intensive industries could be offset by higher emissions in non-regulated countries (Böhringer and Rutherford 2008). This leakage is potentially highest in such emissions-intensive industries as oil and gas, cement, iron and steel, non-metallic minerals, and chemicals.[10]

How can one estimate the change in global emissions if Canada alone were to implement a carbon price? Unfortunately, the general equilibrium model used in our analysis does not differentiate imports and exports by country of origin or destination, but it does tell us what changes are expected in the level of exports and imports of each commodity. We link the change in commodity groups used in the general equilibrium model to the OECD bilateral trade database based on the closest commodity classification.[11] We assumed that the share of each commodity imported and exported by country is the same before and after the introduction of a carbon price. For example, if 60 percent of Canada's imports in the transportation industry originated in the United States before the introduction of the carbon tax, this will be unchanged in the scenario with a carbon tax. However, this is likely to underestimate the extent to which foreign emissions increase in response to a Canadian carbon tax because the high level of aggregation cannot capture the likelihood that the most carbon-intensive production within each industry category is the most likely to be moved from Canada and produced elsewhere.

We assume that, when Canadian exports change due to a carbon price, foreign consumption stays the same, since foreign consumers simply will find a new source for the goods. We also assume that the difference is made up entirely from production in the destination country (see Table 5). We then combine this with the change in emissions from Canada's new profile of imported goods, where changes in emissions are calculated by replacing Canadian production with foreign production. The difference in emissions associated with a given good when produced abroad (Table 5, column 1) as opposed to its being produced in Canada (column

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10 See Fischer and Fox (2004); Demailly and Quirion (2006); Carbon Trust (2007); and Quiroga, Sterner, and Persson (2007) for a review of the literature on emissions exporting.

11 The industries in the general equilibrium model and their counterparts in the related OECD Structural Analysis Database (in parentheses) are as follows: agriculture (agriculture/forestry); oil, gas, and coal (mining and quarrying); other mining (nonmetallic minerals); other manufacturing (textiles, transport equipment, wood and wood products, food and tobacco products, and other manufacturing); pulp and paper (paper, pulp, and print); petroleum refining and chemicals (chemical and petrochemical); other minerals (nonferrous metals); iron and steel (iron and steel). The OECD database identifies, by industry, the value of trade Canada exchanged with each trade partner. We used the most recent year of export and import data levels (2003) and extrapolated these levels to grow at historical annual growth rates to 2020 to create a business-as-usual baseline of levels of trade. We then applied the percentage change of exports and imports of each commodity to the level of exports and imports. The estimated change in emissions between the two countries as a result of changes to trade patterns is based on the estimated reduction in GHG intensity for the Canadian industry as a result of carbon pricing, as estimated in the general equilibrium model.

Table 5: Effect of Changes in Canadian Exports and Imports on Global Emissions Levels, 2020, by Industry

Industry	Foreign Producers Adjust Domestic Production to Replace Change in Canadian Production	Canadian Emissions in Place of Foreign Emissions for Same Production	Net Change in Emissions
	(Mt CO$_2$e emissions change)		
Agriculture/forestry	-0.1	-0.1	0.0
(Petro) chemical	9.7	2.9	6.8
Food and tobacco	-0.8	-0.4	-0.4
Iron and steel	3.6	2.5	1.1
Machinery	-1.6	-0.4	-1.2
Mining and quarrying	12.5	6.7	5.8
Nonferrous metals	8.6	4.8	3.8
Nonmetallic minerals	1.0	0.6	0.4
Paper, pulp, and print	1.0	1.1	-0.1
Textiles and leather	-0.4	-0.1	-0.3
Transportation equipment	-2.8	-1.2	-1.6
Wood and wood products	-1.5	-0.8	-0.7
Total	**29.3**	**15.5**	**13.8**

Source: Authors' calculations from CIMS, DGEEM and OECD Structural Analysis Database.

Table 6: Effect of Changes in Canadian Exports and Imports on Global Emissions Levels, 2020, by Region

Trade Partner	Foreign Producers Adjust Domestic Production to Replace Change in Canadian Production	Canadian Emissions in Place of Foreign Emissions for Same Production	Net Change in Emissions
	(Mt CO$_2$e emissions change)		
Developing (China, India, Russia, Mexico)	0.6	0.2	0.4
Europe (UK, Germany, France, Italy)	0.3	0.5	-0.2
Asia (South Korea, Japan)	0.3	0.4	-0.1
United States	28.1	14.4	13.7
Total	**29.3**	**15.5**	**13.8**

Source: Authors' calculations from CIMS, DGEEM and OECD Structural Analysis Database.

2) is the net change in global emissions (column 3). A negative net change in Table 5 is due to Canada importing goods produced less carbon intensively than if they were produced in Canada, while an increase in emissions means the import profile has shifted to more carbon-intensive international goods than comparable Canadian products.

If Canadian producers were to become less carbon intensive than their international competitors, shifting production abroad could lead to a smaller decrease in emissions than if overall global levels of consumption stayed the same. Unsurprisingly, Canada's most carbon-intensive industries, the chemical and petrochemical industries, would experience the largest loss of foreign markets while facing more import competition. Unfortunately, OECD trade and emissions data are not sufficiently detailed to provide information on the amount of emissions likely to be "leaked" from the Canadian cement industry, an industry particularly prone to carbon leakage (see Demailly and Quirion 2006). More detailed

research on specific industry leakage rates, rather than the overall perspective reported here, should be undertaken before any policies meant to address leakage concerns are implemented.

The 13.8 megatonne increase in emissions elsewhere in the world if Canada were to act alone (see Table 5) is equivalent to an increase of 6 to 7 percent in total Canadian business-as-usual emissions. The reduction in Canadian emissions would be around 33 percent relative to the business-as-usual scenario. In short, for every tonne of reduced Canadian emissions, there would be an increase in foreign emissions of around one-fifth of a tonne.

The majority of emissions from Canadian exported goods are from those destined for the United States (Table 6). If Canada were to reduce exports to that country, the goods that would be produced in the United States instead would result in higher emissions than if they were manufactured in Canada because most Canadian manufacturing industries are less carbon intensive than their US equivalents. On the other hand, increasing imports from the rest of Canada's major trading partners in Europe and Asia would lead to a reduction in net global emissions, since the goods that Canada imports from those countries are produced less carbon intensively there. Large developing countries such as China, India, and Russia have more carbon-intensive production than Canada has, but emissions leakage to these countries is expected to be miniscule for two reasons. First, the amount of trade between Canada and the developing world is small in comparison with Canada's trade with developed countries that are likely to cap emissions. Second, the goods that Canada trades with developed countries are generally low-carbon-intensity goods that are insensitive to carbon pricing.

The concern that Canadian emissions would be displaced to developing countries that lack tough carbon policies is largely unfounded. Fischer and Fox (2007) and Fischer (2008) come to a similar conclusion that leakage from Canada would be predominantly due to trade with the United States. Fischer (2008) finds that a full border tax adjustment – combining both an export rebate and an import tariff – would reduce foreign leakage by around 10 to 15 percent in the iron and steel, elec-

tricity, and chemicals industries and by as much as 29 percent in the petroleum products industry. In contrast, a rebate or tariff alone would have little effect on leakage.

Conclusions and Policy Recommendations

Carbon pricing is the most effective method of reducing emissions of GHGs, whether by some form of cap-and-trade system or a carbon tax. There are, however, challenges associated with the political acceptability of carbon pricing. Its effect would be uneven across sectors, and lobbying efforts by the most affected sectors – the fossil fuel extraction and processing, pulp and paper, metal smelting, chemical, and industrial mineral industries – might threaten the political viability of such a policy. Together, however, these industries represent a fairly small portion of the total economy, and few high-value-added industries would have much to lose from carbon pricing.

If Canada were to introduce a carbon price, the net effect clearly would be a reduction in global emissions. Only a small amount of emissions from Canadian industries likely would be shifted elsewhere. Furthermore, most of the increase in emissions as a result of carbon leakage would be due to Canada's failing to act in concert with the United States instead of with developing countries: competitiveness and leakage likely would be of little concern if Canada did not harmonize its carbon policy with developing countries, as trade with these countries is mainly in non-carbon-intensive goods and the magnitude of trade with these countries is relatively small.

Policy tools such as border tax adjustments or the allocation of free, non-resalable permits could alleviate the loss of competitiveness from the unilateral implementation of a tough carbon-pricing policy, and could also be used to ease opposition to the enactment of effective climate change policy. Such actions, however, could have undesirable effects on the wider economy. They would also face significant technical and legal challenges, and ill prepare Canada for a long-term future with tough carbon pricing.

Appendix

Decomposition Analysis

The logarithmic mean Divisia index (LMDI) method used in this *Commentary* is explained in further detail in Ang (2005) and Bataille et al. (2007). The LMDI decomposes a difference, *V*, in emissions per unit of output in a given industry between regions *C* and *M*, where

$\Delta V = \Delta V_{energy\ int} + \Delta V_{fuelmix} + \Delta V_{emissions}$, *x* is fuel mix, energy intensity, or emissions per unit of fuel, and each component of every fuel and related emissions, *i*, is

$$\Delta V_{xk} = \sum_i \frac{V_i^C - V_i^M}{\ln(V_i^C / V_i^M)} \times \ln\left(\frac{x_{k,i}^C}{x_{k,i}^M}\right)$$

Emissions per dollar of value added from Canadian industries are compared to the average of comparable industries from the other G7 countries (United States, United Kingdom, Italy, Germany, France, and Japan) as well as South Korea and Mexico. This prevents any one country from disproportionately influencing average emissions. In view of the lack of OECD data from 2002 and 2003 for Canadian industries – and an economic slowdown in 2001 – emissions per unit of output are from 2000, the most directly comparable year for country-by-country emissions.

All figures use millions of 2000 US dollars. International and Canadian data are from the OECD Structural Analysis Database and from International Energy Agency (IEA) energy balances and statistics tables, while supplementary Canadian statistics are from the Canadian Industrial Energy End-Use Data and Analysis Centre at the School of Resource and Environmental Management, Simon Fraser University. Missing data, however, required us to ignore the following industries in select countries: machinery and wood and wood products in Mexico; wood and wood products, transport equipment, and textile and leather in Japan; mining and quarrying and nonmetallic minerals in France; and agriculture/forestry and mining and quarrying in the United States.
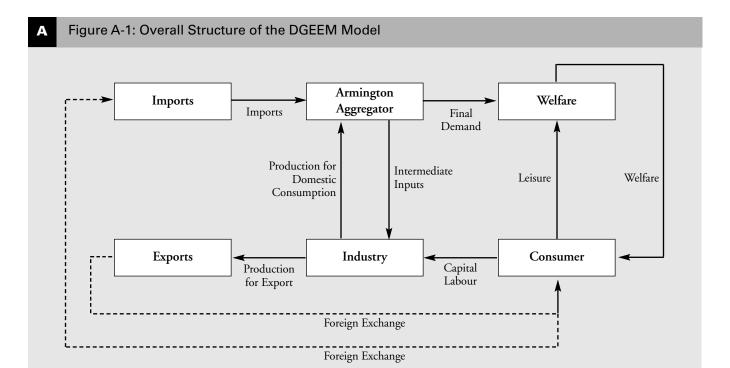
For each country, we linked industry electricity use to the average amount of GHG per kilowatt hour produced by that country's electricity industry. We included only emissions produced by energy use, not emissions from industrial processes, since data on emissions due to fixed industrial processes – emissions that are an inherent product of the production process – are not available from either the OECD or the IEA. Fixed process emissions reductions are not required under the current Canadian Federal (March 2008) Regulatory Framework for Industrial Greenhouse Gas Emissions; provincial regulation of process emissions is still indeterminate.

CIMS

The original design of the CIMS model was related to the National Energy Modeling System of the US Energy Information Administration and subsequently developed for Canada by MK Jaccard & Associates and the Energy and Materials Research Group at Simon Fraser University. It simulates the technological evolution of the energy-using capital stock in the Canadian economy (such as buildings, vehicles, and equipment) and the resulting effect on output, investment, labour and fuel costs, energy use, and emissions of GHGs and local air contaminants. The stock of energy-using capital is tracked in terms of energy service provided (square metres of lighting or space heating) or units of physical product (metric tonnes of market pulp or steel). New capital stocks are acquired as a result of the time-dependent retirement of existing stocks and growth in stock demand. Market shares of technologies competing to meet new stock demand are determined by standard financial factors as well as by behavioural parameters from empirical research on consumer and business consumption and investment preferences. CIMS has three modules – energy supply, energy demand, and the macro-economy – that can be simulated as an integrated model or individually. A model simulation consists of the following basic steps:

A   Figure A-1: Overall Structure of the DGEEM Model

Source: Rivers 2008.

1. A base-case forecast of each sector's physical output initiates model runs.
2. In each time period, some portion of the existing capital stock is retired according to stock lifespan data.
3. Retrofits and prospective technologies compete for new capital stock requirements to replace retired capital stock based on financial considerations (capital costs, operating costs), technological considerations (fuel consumption, lifespan), and consumer preferences (perception of risk, status, comfort) as revealed by behavioural-preference research.
4. The model iterates between its macro-economy, energy supply, and energy demand modules in each time period until a balance has been achieved between energy and goods and services supply and demand.

The key market-share competition in CIMS can be modified depending on evidence about factors that influence technology choices. The financial costs of new technologies can decline as a function of market penetration, reflecting economies of learning and scale, lower technology risks and growing familiarity with a new innovation.

CIMS simulations reflect the energy, economic and physical output, GHG emissions, and CAC emissions for the following sectors: residences, commercial and institutional buildings, personal and freight transportation, industry (chemicals, metal smelting, industrial minerals, pulp and paper, iron and steel, metals and mineral mining, and other manufacturing), energy supply (electricity generation, petroleum refining, petroleum crude extraction, natural gas extraction and processing, and coal mining), agriculture and waste. CIMS does not include adipic and nitric acid, solvents, hydrofluorocarbon emissions, or non-agricultural land use change.

CIMS was recently recalibrated to reflect Environment Canada's *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada 1990-2006,* as well as the department's online *Criteria Air Contaminant Emissions Summaries: 1990-2015.* We also updated the values from *Canada's Energy Outlook 2006 (CEO 2006),* published by Natural Resources Canada, which provides the foundation of CIMS' physical output forecast to 2020, to reflect recently released output, energy,

and emissions data for 2005 from Natural Resources Canada's *Comprehensive Energy Use Database* and Statistics Canada's *Report on Energy Supply and Demand.* For further information on CIMS, see Jaccard et al. (2003); Rivers and Jaccard (2005); and Bataille et al. (2006).

DGEEM

DGEEM (Dynamic General Equilibrium Emissions Model) is a multi-sector, open-economy dynamic computable general equilibrium model of the Canadian economy. In the model, a representative consumer is the owner of the primary factors of production (labour and capital). The consumer rents these factors to producers, who combine them with intermediate inputs to create commodities. These commodities can be sold to other producers (as intermediate inputs), to final consumers, or to the rest of the world as exports. Commodities can also be imported from the rest of the world. Since DGEEM is a small open-economy model, Canada is assumed to be a price taker for internationally traded goods. The key economic flows in DGEEM are captured schematically in Figure A-1. DGEEM assumes that all markets clear – in other words, that prices adjust until supply equals demand. All markets are assumed to be perfectly competitive, such that producers never make excess profits and that supply equals demand. Likewise, factors of pro-

duction are completely employed, so that there is no involuntary unemployment and no non-productive capital.

The version of DGEEM used in this project adopts a dynamic framework, which simulates labour force growth and capital formation over time. Consumers are assumed to maximize utility over multiple time periods by choosing an appropriate rate of investment and consumption in each time period. Under this approach, investment is directly influenced by changes in policy. Changes in investment cause changes in the level of capital stock that firms can employ, which influences overall economic growth and other variables. Like most computable general equilibrium models, DGEEM imposes the restriction of constant returns to scale on producers to make the model more tractable. Likewise, it imposes the assumption that consumer preferences are homothetic. The data underlying the model are derived primarily from Statistics Canada's System of National Accounts. The benchmark year for the model is 2010, extrapolated from 2000-04 data. Energy consumption is disaggregated using data from the CIMS model and from the Natural Resources Canada publication, *Canada's Energy Outlook: The Reference Case to 2006.* DGEEM is implemented in the General Algebraic Modeling System, using the MPS/GE substructure. For more information on DGEEM, see Rivers (2008) and Rivers and Sawyer (2008).

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