Regional Incidence of the Costs of Greenhouse Policy

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Introduction

With the signing of the Kyoto Protocol in 1997, Canada agreed to reduce its greenhouse gas (GHG) emissions to 6 % below 1990 levels. Since then, a number of climate change plans have been produced by the federal government. Action Plan 2000 was followed by the federal government's Climate Change Plan (CCP) in 2002 and then by Project Green (PG) in 2005.[1] Although not identical, the key elements of the federal government's strategy for tackling GHG emissions are similar across plans: a system of tradeable domestic permits, a heavy reliance on voluntary actions, targeted measures and subsidies, limited use of the polluter-pays principle and only a limited role for international permit purchases.

One of the motivating factors behind Project Green (and the CCP) was to ensure that the burden of compliance was spread fairly across the provinces and yet there has been almost no work done to address the issue of how the aggregate costs of this federal plan (or any other) are distributed across provinces. And while the federal approach relies on a mix of policy instruments, much of the attention

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1. See Government of Canada (1998), Government of Canada (2002) and Government of Canada (2005) respectively.

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in the literature has focused on single instrument approaches, like international permit trading or a carbon tax. This paper helps to address these gaps and, in doing so, makes two contributions to the literature. First, we develop a regional, computable general equilibrium (CGE) model of Canada to estimate not only the aggregate welfare effects but also the impact for individual provinces of achieving Canada's Kyoto target using different policy approaches. Second, the model includes features that allow us to represent some of the policy elements that have featured prominently in the federal government's Project Green and earlier climate change plans. In particular, the CGE model allows for the emergence of a new non-fossil electricity sector and new carbon sequestration and sinks activities in response to endogenously-determined federal subsidies and a domestic permit trading scheme with sectoral exemptions and price caps. We also account explicitly for the additional federal costs associated with policy measures that involve direct federal outlays.

A number of studies have looked at the effects of alternative policies for climate change in Canada. The Canada-wide effects of achieving the Kyoto target using a single market based instrument – a carbon permit trading scheme – is estimated using a national CGE model in Ab Iorwerth et al (2000), Wigle (2001) and Dissou et al (2002). These studies find that Kyoto compliance leads to a 1 % to 2 % reduction in real GDP from business-as-usual levels. Dissou (2005) uses a CGE model to compare the effects for Canada of achieving Kyoto compliance using a carbon tax with the alternative of a performance standard. He finds that the performance standard and the permit system (where revenues are used to lower tax rates on factor income) give rise to similar negative effects for real GDP, roughly -0.36 % in both cases. The -0.31 % reduction in welfare with the performance standard is, however, significantly larger than the -0.12 % reduction in welfare that occurs with the permit system.

With a focus on national welfare effects or other aspects of climate change policies, these studies are unable to address the issue of how aggregate costs are distributed across provinces. Those studies that do focus on the provincial implications of Kyoto compliance are based on breaking out the results of a national model using various proportional allocation rules. For example, provinces' historical shares of national GDP are calculated for each sector. After the climate change policy is introduced, the new national GDP is allocated according to these shares. This is the general approach used in Ab Iorwerth et al (2000) and in a number of studies that focus on the 2002 Climate Change Plan.[2] An important drawback of this approach is that it ignores the influence of the different input and output patterns of a given sector among provinces as well as the transmission of shocks between provinces through interprovincial trade.

Most studies consider a single policy instrument rather than a *mix* of policies such as that proposed in Project Green or the CCP for achieving GHG emissions reductions. We are aware of only one study that examines Project Green's particu-

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2. See, for example, Lantz and Murrell (2005) and Government of Canada (2002).

lar mix of policies. Jaccard et al (2006) uses the CIMS model to estimate the effects of Project Green policies on domestic emissions reductions in the short and long runs. CIMS is a "hybrid" model based on very detailed knowledge of the costs and characteristics of available energy technologies. Using their model combined with some assumptions about federal funding levels for climate initiatives and about policy effectiveness, Jaccard et al (2006) compares the simulated emissions reductions for each PG component, and in aggregate, to evaluate the plan's effectiveness. Their results suggest that PG would at best result in emissions reductions of about 175 Mt (with about half of the reductions taking place in Canada) by 2010. Projecting PG policies out to 2040, the authors estimate that the emissions reductions, while below projected business-as-usual levels, will be well in excess of Canada's Kyoto commitment.

While Jaccard et al (2006) focus on aggregate GHG emissions and the costs to the federal government (and taxpayers) of sustaining PG initiatives in the longer run, provincial welfare effects are not considered. Their hybrid model is also very limited in its ability to capture the economy-wide effects of relative price changes and changes in sectoral activity levels that are likely to accompany climate policy. The strength of our regional CGE model is that it is well-equipped to evaluate aggregate and regional welfare effects, relative price changes and shifts in the economy's structure. Our approach cannot, however, take into account the energy detail that is available in the CIMS model and it is ill-suited to the evaluation of the adjustment path and adjustment costs associated with climate change policies. Further, the model is unable to adequately assess how climate policy affects the longer-term attractiveness of investing in Canada. Perhaps the greatest qualification is that CGE modeling requires some assumptions about the underlying elasticities and parameters of the model. Most of the parameters are based on values commonly-used in other studies, but it is clear that substantial uncertainty exists about many of them.

We find that the mix of policies proposed in Project Green is unlikely to achieve the domestic emission reduction targets set out in the plan. Although PG was partly motivated by provincial distributional considerations, the federal government's policy package does not seem to yield a fairer allocation of burden across provinces than a simpler incentive-based approach, like an international permit trading scheme. And while international permit trading also appears to achieve greater emissions reductions at home, all provinces except Ontario prefer PG. The inclusion of voluntary transportation measures (if effective) works to reduce welfare losses in all provinces except Ontario and Newfoundland. Finally, for the simulations we considered, the domestic carbon tax experiment results in the largest aggregate welfare loss, the most uneven distribution of welfare effects across provinces, and the most dramatic changes in activity levels across sectors.

Project Green (2005)

This section provides a very selective overview of the climate change policies included in Project Green. As noted above, PG is similar in many respects to the federal government's earlier plan released in 2002. In many cases, the differences are of emphasis or packaging. Project Green includes several key elements:

- The Climate Fund will purchase domestic greenhouse gas reductions from farmers, businesses, communities, Canadians, and other innovators and secure international reductions/credits. In a sense, this repackages the trading that could have occurred under the 2002 plan. The plan quotes a reduction in emissions of 75-115 Mt to be achieved through this fund.[3]
- The Partnership Fund will make strategic investments and create partnerships with the provinces and territories to achieve GHG emissions reductions in the range of 55-85 Mt. The types of projects to result include landfill gas capture; phase out of coal; clean coal; CO_2 capture and storage; and enhancement of the East-West electricity grid.
- Large Final Emitters (LFE) include the oil and gas sector, thermal electricity, mining and energy-intensive parts of manufacturing. These sectors are expected under PG to achieve a rather modest reduction (36 Mt) via a domestic tradeable permit scheme (DET). Several aspects of the scheme reduce the compliance cost to firms. The permits are grandfathered (meaning that firms are only required to achieve reductions below a certain reference amount) and reductions are intensity-based. That is to say that a firm has to achieve a certain level of emissions per unit of output, either by their abatement activities or the acquisition of DET permits. Firms exceeding their target reduction may sell the DETs. There is a price ceiling of $15 imposed on the permits, and no firm is required to make an overall reduction of more than 12 %. Further, a distinction is made between emissions that can only be reduced by reducing output (fixed process emissions) and other emissions. Firms are not required to make reductions to fixed process emissions.
- There are a number of GHG reduction programs that provide incentives (subsidies) to retrofit older buildings to be more energy efficient or to switch to lower emission fuels in transportation.
- Canada receives some credits for its carbon sinks (i.e. not changing existing forestry and farming practices, which would be expected, in a typical year, to absorb some amount of CO_2 from the atmosphere. Credits from these business-as-usual practices contribute 30 Mt to Canada's required emissions reduction target under Kyoto. The federal plan also hopes to generate some further credits through forestry and land-use (agriculture) changes using the Climate Fund and other government initiatives.
- Renewable energy initiatives to encourage the expansion of wind, solar, and

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3. The implies a cost of CO_2 of $35 to $67 per tonne. This is rather surprising, given that the plan was nominally based on a world price of credits in the range of $10-15 per tonne.

TABLE 1 Backgrounder for Project Green 2005

	PG 2005		CCP 2002[1]
	Mt	**$B[2]**	**Mt**
Climate Fund[3]	75 to 115	4 to 5	--
Partnership Fund	55 to 85	2 to 3	--
Large Final Emitters	36	--	55
GHG Reduction Programs	40	2 to 3	--
Carbon Sinks	30	--	38
Renewable Energy	15	1	23
Consumer Action	5	1[4]	7
Automotive Industry	5.3	--	21
Greening Government	1	--	0.2
Other Credits[5]	2	--	2
Other	--	--	123.8
Total	270	10 to 13	270

Note:
1. The CCP targets are presented for comparison purposes.
2. Estimated costs to the federal government over the period from 2005-2012 are taken from Annex 1 of Government of Canada (2005).
3. Assumes the additional domestic credits and international credits will be available at $10/t.
4. $120 million in additional funds are allocated to the 1 Tonne Challenge.
5. For contribution to the World Carbon Fund.

small-scale hydro electricity through incentives (subsidies) and regulatory changes with the expectation that renewable energy would contribute about 15 Mt of the required reductions for 2008-2012.

- Through the promotion of voluntary actions on the part of consumers, PG hopes to add further reductions. This includes the 1 tonne Challenge.
- The auto industry was exempted from the LFE permit scheme, but signed a Memorandum of Understanding (MOU) with the federal government that commits them to reduce average fleet emissions of cars and light-duty trucks by (roughly) 25 % by 2012. The MOU also indicated that auto firms are not responsible for emissions changes caused by things that the auto industry “can't control”. [4]

A breakdown of reductions for both Project Green and the Climate Change Plan are shown in Table 1. The presentation of PG is more aggregated than CCP so it is not possible to provide a direct one-to-one correspondence between the two plans but the content of the two plans is nevertheless very similar. Both Project Green and the 2002 plan were criticized for excessive reliance on voluntary measures and the fact that punitive (polluter pays) measures were shunned in

4. According to the MOU, this includes vehicle sales and sales mix; scrappage of vehicles, and the profile of annual kilometres travelled by vehicle age. See Government of Canada and Canadian Automotive Industry (2005).

favour of incentives or subsidies.[5]

Overall, the 2005 plan looks quite like the 2002 plan. From a packaging perspective, the main difference in Project Green from CCP is that it rolls various CCP initiatives and measures into more aggregated "policy" categories and attaches reduction targets to these broader categories. In contrast, CCP provided emissions reduction goals for a detailed listing of initiatives. For the purposes of our CGE model described below, we use the detailed targets from CCP when necessary to help modify the model to reflect policy elements in Project Green.

Model and Data Overview

This section gives a brief overview of the model and 2010 data used in the paper.

CREAP Data

The 2010 CREAP data used is based on the 1998 S-level Input Output Tables prepared by the IO Division of Statistics Canada.[6] This data comprises a final demand matrix, a trade matrix (including interprovincial and international trade) as well as Input and Output matrices. These last two represent the productive sectors. The S-level data includes 23 productive sectors and 56 goods. A given sector produces many goods.

The S-level aggregation does not separately identify energy goods (coal, natural gas, refined petroleum products and electricity), and these goods were disaggregated to produce the CREAP data for 1998. The data includes a detailed allocation of indirect taxes (including GST and gasoline taxes) to all the transactions in the model.

The data used in this paper are a 2010 baseline, obtained from the 1998 CREAP data so as to reproduce the pattern of provincial domestic product (RDP) by sector and province, as well as provincial emissions outlined in the Canadian Emissions Outlook and Update. Emissions are associated with the burning of fuels (coal, natural gas and refined petroleum products) as well as natural gas and oil extraction (fugitive emissions). All nominal values are in millions of 1998 Canadian dollars.

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5. See, for example, Jaccard et al (2004) which questions the effectiveness of most of the measures in the 2002 plan.
6. See Input-Output Division (2003).

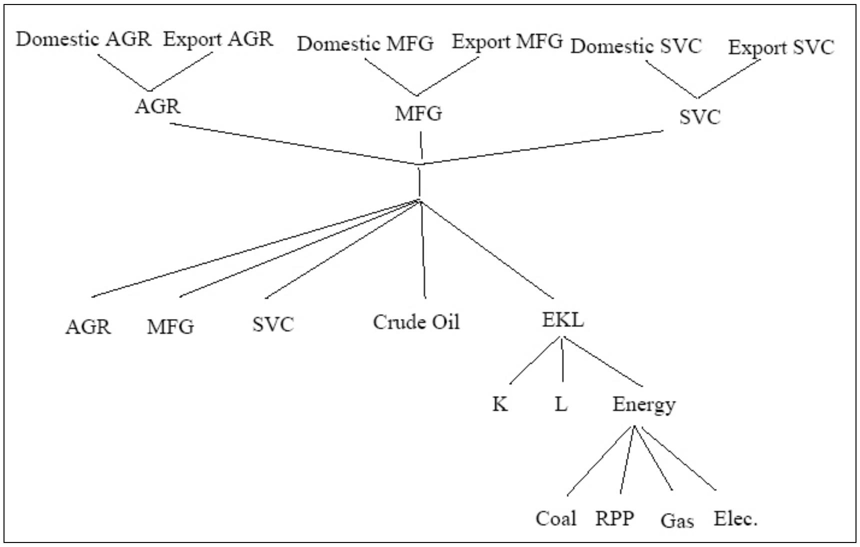

FIGURE 1 Tree Diagram of Production Structure

CMRT Model

CMRT is a static CGE provincial model of Canada based on the BMRT model. The structure of production, consumption and trade in the model corresponds to the BMRT model, described in detail in the BMRT documentation.[7] This section focuses on its general characteristics, providing more detail on the characteristics which separate it from BMRT.

Production

As in the data, each sector in the model produces several goods using a nested CES/CET production technology. All production exhibits constant returns to scale and perfect competition. The structure of substitution between inputs is described in Figure 1.

In the figure, all non-energy goods are represented by the goods AGR, MFG, and SVC which denote agricultural goods, manufactured good,s and services respectively. RPP refers to refined petroleum products. Emissions from burning of fuels as well as fugitive emissions associated with production of oil and natural gas are fixed proportions inputs of greenhouse gases. Each sector earns zero profits.

Each sector produces a range of output goods. Output transformation among a given sector's output goods is governed by a CET transformation function. Each

7. Documentation available at http://creap.wlu.ca/creap-models.html.

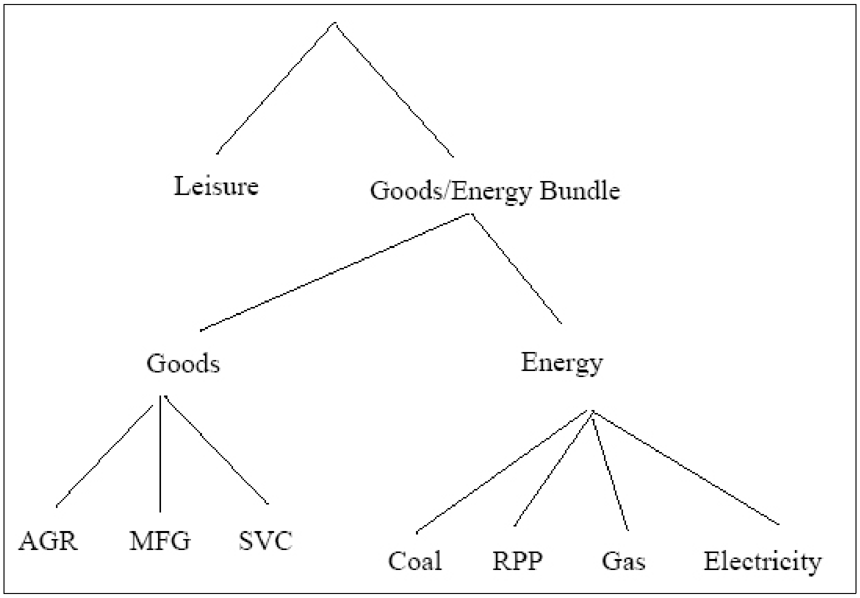

FIGURE 2 Tree Diagram of Representative Agent's Preferences

good is further transformed between a domestic variety (for the domestic market only) and an export variant (for the export market).

Provincial Representative Agents and Final Demand

Preferences are represented as nested CES functions of leisure and Armington composites of all the produced goods. Private and public consumption as well as private and public investment are all lumped together in this treatment. The structure of preferences is illustrated in Figure 2.

Trade and Import Aggregation

Final demand and intermediate use are of "Armington" composites of domestic and imported versions of a given good as shown in Figure 3. So, for example, the intermediate use of electrical parts is a composite of domestic and foreign parts.

The intermediate and final Armington composites are the same. In other words, when a given province's consumers buy electrical products, they get the same share of own-province to PEI to Rest of World electrical products that province's industry users do. This simplifies the model somewhat and we are unaware of any data to distinguish between the two.

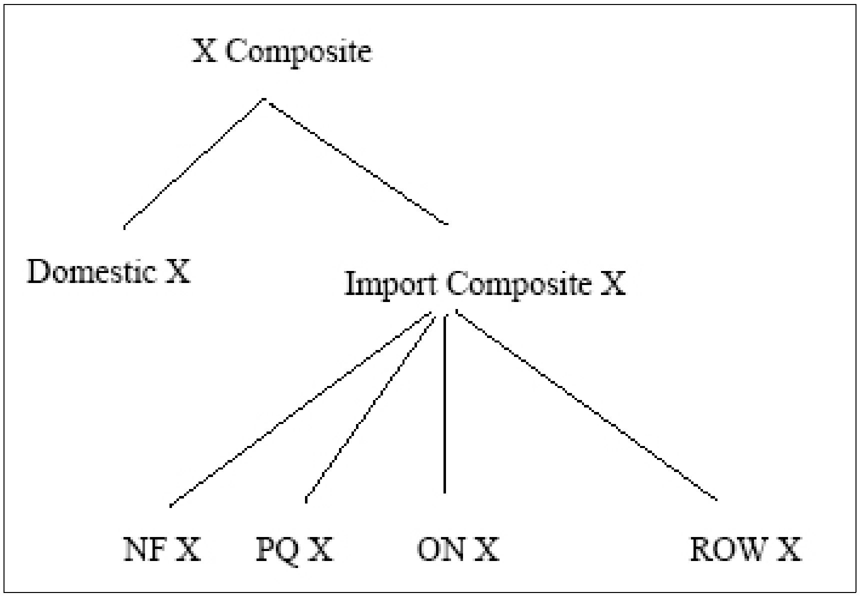

FIGURE 3 Structure of Domestic-Imports Substitution

Rest of World

The Rest of World (W) is represented by two types of activities. Export activities (1 per commodity) take inputs of foreign exchange and produce W exports. Import activities (1 per commodity per province) take inputs of Canadian provincial exports and produce foreign exchange. Each province has a balance of payments which is fixed in real terms.

Energy/GHG Features

In the model, emissions are treated as a fixed-coefficient “input” of emissions associated with the burning of fossil fuels or the production of crude oil or natural gas. As noted in the diagrams above, there is substitution between energy and non-energy inputs as well as substitution among energy sources. With this set-up, both BMRT and CMRT have the capability of representing tradeable GHG permits and endogenous carbon taxes.

The CMRT model differs from BMRT in that some additional features are included so we can represent a selection of key PG policy elements. With these added features we are able to compare the PG package of greenhouse gas policies with two single instrument alternatives to achieving our Kyoto target, international permit trading and a domestic carbon tax.

New Renewable Electricity

PG includes measures to encourage the expansion of various forms of renewable energy, including renewable (non-fossil) electricity, wind and solar power. In the model, electricity is generated using a bundle of inputs including coal, refined petroleum products and natural gas. We specify a series of incremental renewable non-fossil electricity sectors in each province. These sectors use the same input mix used to produce electricity except that they directly use no fossil fuels. We specify 8 subsectors, each with a different marginal cost of producing electricity, and a limited capacity. This results in a step supply function of additional renewable electricity for each province. The specification is chosen to approximate the supply curve presented in Resources for the Future (2004). The cost disadvantages range from slight (7 %) to significant (over 60 %) relative to conventional electricity. All of the sectors are *inactive (unprofitable)* in the baseline data. One or more of the new sectors may become *active* or profitable as a result of subsidies or an increased price of electricity caused by the taxation of fossil fuels. Total capacity is allocated across the provinces in proportion to that province's 2010 reference renewable electricity.

Sequestration and Sinks

With PG, the federal government plans to encourage and stimulate strategic investments in "clean technologies" such as CO_2 capture and storage using the Partnership Fund. Through the Climate Fund and other initiatives, the federal government intends to promote the creation of new carbon sinks or new carbon sequestration activities.

CO_2 capture and storage involves extracting the CO_2 emissions from a fossil-fired electricity-generating facility and injecting these below ground. There remains some uncertainty about the cost-effectiveness of this technology, but its promotion is included in PG, the federal government's earlier plan and elsewhere.[8] We represent this technology as a productive sector that takes an input bundle similar to the mining industry and produces carbon sequestration (effectively reduced emissions) at a pre-specified cost per tonne. In the absence of climate policy, the activity is unprofitable and inactive because the "price" of GHG abatement is zero. The activity may become profitable, and therefore a viable activity, either through subsidies or if climate policy raises the value of GHG abatement above the unit cost of the technology. We assume that the cost of storing one tonne of CO_2 is \$75 in our central case runs.[9]

By promoting forest growth and adopting alternative crop practices, CO_2 is removed from the atmosphere and new carbon sinks created. In our model we represent this activity as the use of some resources to promote the natural changes in landscape that qualify for credits under the Kyoto Protocol. Currently, we use

8. See Jaccard et al (2004).
9. This is at the upper end of estimates of the marginal cost of these activities.

the same technology and cost of producing one tonne CO_2 credits in this way as carbon sequestration.[10] In the near term we hope to introduce a separate technology using an input bundle resembling that of the agriculture or forestry sector.

Permit Trading and Coverage

CMRT has the capability of representing tradeable GHG permits and endogenous carbon taxes. PG calls for a domestic tradeable permit scheme (DET) to achieve emissions reductions from the largest final emitters only. All other sectors are exempted. Our model allows us to consider variants of a DET scheme where some sectors are completely covered while others are 100 % exempt. We represent exemptions as a 100 % subsidy on permit purchases by firms in the exempt sector.

Transportation Measures

While the auto industry is exempt from the domestic permit scheme under PG, voluntary accords, including agreements to use more fuel blends, encourage driver training to improve fuel economy, and adapt more energy efficient scheduling, may impact on emissions from the transportation sector and from final demand. To reflect this, the model requires the transportation sector to lower its inputs of petroleum products per unit of activity to 1 % below the reference level. Similarly, the petroleum product intensity in final demand is restricted to be no more than 99% of its reference level. These restrictions are collectively referred to as transportation measures. Our central case experiment considers the case where the voluntary agreements are effective (and so the transportation measures are active) but we also consider the case where these agreements are completely ineffective and so the transportation measures are inactive or turned off in the model.

Revenue Distribution

As noted in Table 1, the direct costs to the federal government of PG initiatives were estimated in the range of $10 to $13 billion. Rather than adopt the plan's cost estimate, our simulations include as costs any endogenously-determined federal subsidies required to ensure targets for the “new sectors” and sequestration activities are met as well as government outlays to purchase international permits. As a result of its extensive fragmentation, Snoddon and Wigle (2005) estimate that PG may cost at least $600 million more to administer than some alternatives. Thus, for PG and PG-nt we include this added administration cost to the amounts spent on international permits and subsidies.

We assume that federal expenses are financed by reducing the federal government's transfers to a given province in proportion to that province’s direct tax payments. With the significant detail on direct and indirect taxes in the CREAP

10. See van Kooten (2003) for some discussion of the cost of these activities.

data, alternatives to this financing assumption could be considered. Here, with a focus on comparing the distribution of provincial burdens under the policy alternatives, we assume direct and indirect tax rates are unchanged in all experiments. Alternative financing rules for climate change policies considered in Snoddon and Wigle (forthcoming) are found to have modest impacts. Their main results suggest that in the event where climate change policies generate a revenue shortfall, the welfare costs are likely to be somewhat higher and more uneven across provinces if the shortfall is financed through raising indirect taxes, rather than reducing transfers.

Model Calibration

It is common to use so-called hybrid models such as CIMS to represent the energy side of the economy in many analyses of climate change.[11] CIMS is based on very detailed knowledge of the costs and characteristics of available energy technologies and it yields detailed cost-curves for alternative depths of cut in GHG emissions. Because CMRT's representation of the energy side of the economy is very broad-brush we wanted to make sure that it reproduced a similar result, at least in aggregate, to CIMS.

We chose model parameters to calibrate CMRT to CIMS' overall emissions reduction when used to reproduce a CO_2 tax of $30. This is a policy regime which can be represented in CMRT in the most similar way to CIMS. We chose the $30 price for CO_2 because it is close to the region of the cost curve where most of our runs lie.

The structures of CIMS and CMRT are quite different, so it is impossible to calibrate one to look like the other in all respects. In particular, CIMS takes the energy service demands as exogenous, whereas they are necessarily endogenous in CMRT.

Experiments

Our main interest is to compare the pattern of burden given the Project Green policy package with two policy alternatives, a domestic carbon tax and international permit trading. Note that in this model a domestic carbon tax would be exactly the same as a domestic auctioned permits scheme.

Our benchmark experiment is the Project Green policy package and is denoted PG. We assume that the manufacturing, electricity generation and oil and gas sectors are fully covered by the domestic emissions trading scheme and the price of permits to these sectors is capped at $15. Transportation measures are active as is the new non-fossil electricity sector. In all of the runs, the price of electricity fails to increase enough to offset the cost disadvantage for the new non-fossil sector so an endogenously-determined subsidy to the sector is required to achieve

11. See Mark Jaccard Associates (2003).

the 6.9 Mt emissions reduction target.[12] In this experiment, both the CO_2 capture and storage technology/sector and the sector representing the new carbon sequestration activities are active. Endogenously determined, sector-specific subsidies are again required to assure that the sectors remain viable and achieve a combined target reduction of 8 Mt.[13] One future refinement of the model will separately specify the afforestation, agricultural and CO_2 capture technologies. Having said this, it is clear that the marginal cost of sequestering more than 8-9 Mt is likely to be very high (approaching $200/t). [14]

There are other measures included in PG but we do not include these in our benchmark experiment. In particular, voluntary measures aimed at consumers, such as the one-tonne challenge, are assumed to be completely ineffective. Two additional features are considered. First, Canada has some credits from existing carbon sinks and contributions to the World Carbon Fund that can be counted towards its reduction target of 270 Mt. In all experiments, these pre-existing credits (equal to 32 Mt) are taken into account by adjusting Canada's emissions reduction target accordingly. Second, where the reduction in emissions (from policies and pre-existing credits) falls short of the Kyoto target, we assume that the gap is addressed by purchasing international permits. The required purchases of international permits are endogenously-determined in the experiment.

The three other experiments are PG-nt, Domestic and IPT. PG-nt is identical to PG except the transportation measures are assumed to be inactive (or completely ineffective). In Domestic, we consider the case where a domestic carbon tax is used so as to achieve all required emissions reductions domestically. The carbon tax applies to all emitters of CO_2. Finally, IPT refers to the experiment where our Kyoto target is achieved through international permit trading only. In Domestic and in IPT, new carbon sinks, CO_2 capture and storage and new non-fossil electricity are active only if the policy measures raise the price of CO_2 high enough for the activities to be viable. In IPT, the price rise is sufficient for a small amount of new renewable electricity to come on stream (about 3 % expansion of renewable electricity generation), but neither carbon capture and sequestration nor sinks are pursued. In Domestic, with its higher price on emissions, more renewable electricity (about a 10 % expansion) and new carbon sinks/sequestration activity (about 9 Mt) is active.

Table 2 summarizes our four climate policy experiments.

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12. More precisely, PG specified a goal of 15 Mt from all renewable energy measures. For renewable electricity (a component of renewable energy), we adopt the CCP target of 6.9 Mt.
13. CCP specifies a target of 5.7 Mt for CO_2 capture and storage and a separate target of 8 Mt for additional carbon sinks. In our model, we set the target for these activities combined at 8 Mt (rather than the larger target of 13.7 Mt). There are several reasons for our more conservative target choice. First while it would be possible to use afforestation to sequester more than 8 Mt, Mark Jaccard Associates (2003) argues that the marginal cost of sequestration and afforestation beyond that point is very high. PG also casts doubt on the magnitude of credits for existing carbon sinks given forest fires in British Columbia as well as the Mountain Pine Beetle infestation. To reflect these various uncertainties we adopt a target of 8 Mt for CO_2 capture and storage and carbon sinks combined.
14. See also van Kooten et al (1995).

TABLE 2 Representation of the Four Experiments

Policy Elements		PG	PG-nt	Domestic	IPT
(i)	Domestic Permits (% of sector covered)				
	Mining & Oil & Gas	100%	100%	100%	100%
	Utilities	100%	100%	100%	100%
	Manufacturing	100%	100%	100%	100%
	All other sectors	0%	0%	100%	100%
	Price Ceiling	\$15/t CO_{2e}	\$15/t CO_{2e}	None	None
(ii)	Transportation Measures[2]	Yes	No	No	No
(iii)	New Renewable/ Non fossil Electricity	Yes	Yes	No	No
(iv)	CO_2 Capture & Storage	Yes	Yes	No	No
(v)	New Carbon Sinks	Yes	Yes	No	No
Emissions Reductions From					
	(i) to (v)	X_{PG}[1]	$X_{PG\text{-}nt}$	X_{Dom}	X_{IPT}
	Pre-existing credits	32	32	32	32
	International permits	270-(32+ X_{PG})	270-(32+ $X_{PG\text{-}nt}$)	270-(32+ X_{Dom})	270-(32+ X_{IPT})
Total Emissions Reductions		270 Mt	270 Mt	270 Mt	270 Mt
Direct Expenditures		\$600	\$600	\$0	\$0

Note: 1. X_Z refers to the emissions reductions achieved given the particular set of policies for experiment Z. We assume that international permits must be purchased to ensure the Kyoto target is achieved.
2. For (ii) to (v), yes indicates for that particular experiment that there are special provisions/measures in place (i.e. subsidies) to target that activity or area. A no indicates that there are no special policy measures in place for that activity or area.

Key Uncertainties

In any analysis of GHG policy, there is significant uncertainty. In our case, this includes the world price of permits, the costliness of renewable power, and the costliness of carbon sinks and sequestration activities. There are still questions about the price and viability of an international permit market, focusing on Russia's strategy. They may try to sell as many permits as they can (which could mean a price of permits below \$10), or they could bank a significant number of permits, leading to a price closer to \$50 than \$10 per tonne. The cost of significant additional renewable electricity is subject to some uncertainty and there is still significant debate about the cost of obtaining carbon sinks via forestry, agriculture and through CO_2 capture and storage. On top of these uncertainties are significant uncertainties related to model parameterization. Further work is needed to evaluate the sensitivity of results to the uncertainties, including parameter uncertainty.

TABLE 3 Summary Table – Project Green

	Welfare $M	Welfare %	CO_2 Emissions %
NF	-20.58	-0.10	-2.29
PE	-9.09	-0.21	-0.64
NS	-69.99	-0.21	-5.55
NB	-14.99	-0.06	-2.10
QC	-1390.65	-0.54	-2.40
ON	-4026.73	-0.85	-3.58
MB	-214.56	-0.51	-3.51
SK	-81.82	-0.20	-8.14
AB	-199.48	-0.14	-8.62
BC	-857.56	-0.52	-3.20
Canada	-6885.45	-0.57	-5.69
Price of CO_2		$30.6 per tonne	

Findings

In experiment PG, the welfare cost of Kyoto compliance for Canada is about $7 billion or about 0.6 % of GDP. Even though most users of GHG are shielded from paying it (through broad sectoral exemptions from GHG permit trading) the implied marginal cost of GHG abatement is about $30/t CO_2. Table 3 shows the welfare and emissions effects by province and in aggregate from the PG experiment.

Because of the broad-based exemptions for many emitters and the price caps for the LFE's, the reduction in domestic CO_2 emissions is modest at about 5.7 %. The bulk of Canada's Kyoto commitment is achieved by international emissions trading. In this case, 188 Mt of permits must be acquired by the federal government. Most of these are effectively given free to emitters (large and small) but a small number are sold to LFE emitters for $15/t. The total cost of the international permits purchased represents a significant share of the welfare effect.

One of the selling points for the 2002 Plan, and by implication PG, was that it yielded a similar burden across provinces. We find that the welfare effects range from a minimum loss of .06 % for New Brunswick to a maximum welfare loss of 0.85 % for Ontario.

By way of example, we present sectoral overviews for the utilities, mining and manufacturing sectors by province in Table 4. Some regularities can be noted. First, emissions in the mining and utilities sectors (LFE-covered sectors) fall in almost all cases, the notable exception being utilities and mining in PEI. Having said this, activity in the mining sector declines in some provinces and expand in others. The utilities sector (including electricity generating) expands in BC, Quebec, NF and PEI and declines in the other provinces. Emissions fall in the manufacturing sector in all provinces while activity in the sector increases in all provinces except Saskatchewan and Alberta. The manufacturing sector makes a wide range of goods, and its activity level seems to be determined more by the general equilibrium impacts on demand for manufactures than by the direct impact of the LFE system. Most notably, outside of these sectors, most of the sectoral realloca-

TABLE 4 Summary Results for Selected Sectors – Project Green

		Employment (%)	Sectoral Activity (%)	CO_2 Emissions (%)
NF	Utilities	1.23	1.26	-0.68
	Mining	-2.24	-2.23	-7.43
	Manufacturing	0.78	0.74	-5.17
PE	Utilities	1.21	1.16	0.10
	Mining	1.61	1.47	0.21
	Manufacturing	0.55	0.48	-0.83
NS	Utilities	-2.73	-2.94	-12.85
	Mining	-9.81	-10.24	-18.63
	Manufacturing	2.36	2.38	-9.87
NB	Utilities	-0.14	-0.32	-4.43
	Mining	-6.65	-7.02	-13.04
	Manufacturing	0.36	0.28	-2.88
QC	Utilities	0.62	0.49	-0.52
	Mining	0.90	0.80	-0.63
	Manufacturing	0.22	0.10	-4.44
ON	Utilities	-2.05	-2.30	-7.36
	Mining	2.53	2.40	-1.49
	Manufacturing	0.77	0.67	-2.95
MB	Utilities	0.12	-0.02	-16.59
	Mining	-0.08	-0.15	-1.09
	Manufacturing	1.24	1.18	-8.21
SK	Utilities	-10.43	-11.34	-17.37
	Mining	-1.81	-1.76	0.00
	Manufacturing	-1.34	-1.51	-3.95
AB	Utilities	-7.86	-8.63	-18.45
	Mining	-0.02	0.15	-9.77
	Manufacturing	-1.56	-1.69	-4.74
BC	Utilities	0.60	0.47	-2.92
	Mining	-0.95	-1.05	-4.13
	Manufacturing	0.26	0.13	-7.19

tions caused by the plan are modest. Once again, this may have been the intent of the plan.

One earlier study argued that many of the transportation-related measures proposed in the 2002 plan were unlikely to have a significant effect. By way of a sensitivity run, we reproduced our PG runs, but with no transportation-related measures (denoted PG-nt). This run is summarized in Table 5. With similar aggregate welfare and emissions effects and the same marginal cost of GHG abatement, the two cases are distinguished primarily by differences in the distribution of burden across provinces and across sectors.

First, comparing the results in Tables 3 and 5, effective transportation measures significantly reduce the welfare loss from PG in New Brunswick and PEI while increasing the losses in Ontario and Newfoundland. Second, sectoral activity

TABLE 5 Summary Table – PG-nt (No Transportation Measures)

	Welfare $M	Welfare %	CO_2 Emissions %
NF	0.09	0.00	-1.87
PE	-23.22	-0.53	-0.78
NS	-73.34	-0.22	-5.41
NB	-67.26	-0.27	-2.00
QC	-1427.27	-0.56	-1.74
ON	-3789.12	-0.80	-3.44
MB	-232.93	-0.55	-3.08
SK	-75.35	-0.19	-8.32
AB	-207.83	-0.15	-8.58
BC	-849.64	-0.52	-2.73
Canada	-6745.88	-0.56	-5.55
Price of CO_2		$30.5 per tonne	

TABLE 6 Transportation Sectors – PG and PG-nt

	PG		PG-nt	
	Sectoral Activity (%)	CO_2 Emissions (%)	Sectoral Activity (%)	CO_2 Emissions (%)
NF	-2.19	-3.19	0.99	0.95
PE	-4.35	-5.48	1.32	1.25
NS	-0.72	-1.22	2.15	1.49
NB	-2.29	-2.98	2.22	2.14
QC	-2.64	-3.57	1.57	1.50
ON	-0.68	-1.45	2.80	2.73
MB	-2.22	-3.06	0.47	0.25
SK	3.00	2.35	9.92	9.82
AB	0.99	0.26	5.14	5.09
BC	-1.52	-2.35	2.08	1.95

and GHG emissions in the transportation sector are reduced when effective transportation measures are combined with other PG policies. Table 6 summarizes the impact on provincial transportation sectors in the PG and PG-nt experiments. Provincial transportation sectors *expand* on average about 2.9 % if transportation measures are ineffective. In a few provinces, the expansion is dramatic. For example, in Saskatchewan, sectoral activity in transportation increases 9.9 % and, in Alberta, the sector expands by 5.1 %.

This result is easy to understand, given the mechanisms by which PG works. PG seeks to dampen demand for GHG's and thereby fuels, especially in some sectors which use them heavily. Since PG has limited direct impact on the supply of fuels, the result is downward pressure on fuel prices, which, in the absence of other measures (as is the case in PG-nt) causes the transportation sector (and emissions associated with it) to rise. In effect, this run exposes one of the concerns about the limited use of user-pays instruments in PG. This experiment also raises the question of the effectiveness of voluntary measures. For example, since On-

TABLE 7 Summary Table – Domestic

	Welfare $M	Welfare %	CO_2 Emissions %
NF	-355.91	-1.69	-18.11
PE	-169.95	-3.91	-20.60
NS	-191.03	-0.57	-30.69
NB	-486.87	-1.97	-24.09
QC	-5977.81	-2.33	-15.69
ON	-13083.31	-2.77	-17.77
MB	-1079.76	-2.56	-17.16
SK	231.82	0.57	-36.65
AB	2146.44	1.52	-34.19
BC	-3939.72	-2.41	-18.12
Canada	-22906.09	-1.91	-26.04
Price of CO_2		$153.2 per tonne	

tario (and Ontario's transportation sector) is worse off with the transportation measures and since these measures are voluntary, it is reasonable to ask about the likelihood that these measures would actually be undertaken.

Table 7 shows the results from the domestic carbon tax experiment. The aggregate welfare loss is dramatically higher at 1.9 %, more than triple the aggregate welfare loss in the PG and PG-nt experiments. With the carbon tax, domestic CO_2 emissions fall by 26 % (enough to satisfy the Kyoto target) as compared to a reduction in domestic emissions of 5.7 % in PG. The range of welfare effects is substantially greater under a domestic carbon tax than in the case of PG. Ontario, Manitoba, Quebec and Prince Edward Island are the biggest losers in this experiment while Alberta and Saskatchewan experience welfare gains of 1.52 % and 0.57 % respectively. These results are partially due to the implementation of the carbon tax in the model. We assumed that the revenue associated with the carbon tax is distributed to the provinces in proportion to their initial emissions. Provinces with high emissions as a rate of RDP then receive a higher share of the revenues. If, further, it is relatively easy to reduce emissions, the province may gain more from carbon tax revenue than they pay to reduce their emissions. In our model this appears to be the case for Saskatchewan and Alberta. Further to this, Alberta and Saskatchewan have a large share of the capacity for creating carbon sinks through forests and agriculture. These activities come on line when the price of CO_2 is very high. As a consequence, significant rents accrue to Alberta and Saskatchewan.

The effect of a carbon tax on the pattern of sectoral activity is much more dramatic than under PG. The results for selected sectors and provinces are illustrated in Table 8. These radical changes highlight a main difference between a hybrid model like CIMS and our regional CGE model, CMRT. CIMS simulations like those undertaken in Jaccard et al (2006) and Jaccard et al (2004) assume that the activity levels of sectors are unchanged by policy. In our CMRT model, the activity levels of sectors are endogenously determined. In this experiment, the domestic carbon tax leads to large structural shifts and, by implication, dramatic changes in the sectoral pattern of energy services demands. Moreover, the regional CGE model demonstrates that the changes in sectoral activity in response to a

TABLE 8 Summary Results for Selected Sectors and Provinces – Domestic

		Employment (%)	Sectoral Activity (%)	CO_2 Emissions (%)
NB	Utilities	-4.21	-5.40	-16.09
	Mining	-46.81	-48.34	-56.10
	Manufacturing	0.12	-0.30	-12.08
	Transportation	-24.82	-25.87	-31.62
QC	Utilities	7.92	7.49	1.03
	Mining	4.83	4.34	-3.82
	Manufacturing	-0.45	-0.95	-15.02
	Transportation	-21.15	-22.27	-26.30
ON	Utilities	-12.92	-14.28	-25.55
	Mining	10.73	10.17	-3.14
	Manufacturing	1.79	1.42	-10.24
	Transportation	-7.17	-8.04	-12.83
SK	Utilities	-48.22	-51.01	-57.04
	Mining	79.61	81.99	0
	Manufacturing	-48.72	-49.24	-53.88
	Transportation	-10.92	-11.65	-19.23
AB	Utilities	-38.16	-41.32	-51.17
	Mining	2.51	3.79	-17.12
	Manufacturing	-30.36	-31.38	-38.08
	Transportation	-14.04	-14.81	-20.54

TABLE 9 Summary Table – IPT

	Welfare $M	Welfare %	CO_2 Emissions %
NF	-47.11	-0.22	-6.29
PE	-54.58	-1.25	-8.02
NS	-98.52	-0.30	-15.56
NB	-165.12	-0.67	-10.63
QC	-1377.45	-0.54	-5.80
ON	-3356.67	-0.71	-7.42
MB	-256.62	-0.61	-8.71
SK	-236.15	-0.59	-17.50
AB	-657.14	-0.46	-15.76
BC	-878.65	-0.54	-7.40
Canada	-7128.0	-0.59	-11.67
Price of CO_2		$30.3 per tonne	

domestic carbon tax give rise to a very uneven distribution of the burden across provinces.

Finally, we look at the case where Canada completely integrates into the world market for CO_2, under the assumption that the world price of CO_2 is $C30/t. This experiment is summarized in Table 9. Two things are notable. First, the Canada-wide welfare cost is quite similar to that associated with PG, but domestic

TABLE 10 Provincial Welfare Comparison – PG vs IPT

	PG Welfare %	IPT Welfare %
NF	-0.10	-0.22
PE	-0.21	-1.25
NS	-0.21	-0.30
NB	-0.06	-0.67
QC	-0.54	-0.54
ON	-0.85	-0.71
MB	-0.51	-0.61
SK	-0.20	-0.59
AB	-0.14	-0.46
BC	-0.52	-0.54
Canada	-0.57	-0.59

emissions fall much more. There are no sectoral exemptions associated with this scheme, and the costs of GHG permits are passed on to all domestic emitters.

The second remarkable thing about IPT is that, with a few exceptions, the welfare effects are remarkably similar across provinces. With the exception of PEI and Newfoundland, the welfare costs range from 0.30 % to 0.71 %, less than one percent of GDP. Only PEI has a significantly *higher* cost than other provinces, at 1.25 %. Addressing the concerns of PEI (i.e. increasing transfers enough to reduce their burden to the national average of 0.6 %) would be relatively straightforward.

Compared to PG, IPT achieves a similar welfare loss in aggregate, greater domestic emissions reductions and a similar range of provincial welfare burdens. However, from Table 10, it is clear that based on welfare losses alone only Ontario prefers the IPT option. Quebec is indifferent but all other provinces prefer, and in some cases, strongly prefer, Project Green's outcome to IPT. It is interesting to note that sectoral impacts are broadly comparable in PG and IPT. Table 11 shows the effects on the activity levels in selected sectors and provinces for the two experiments. These results are fairly representative of the magnitude of effects in other sectors and provinces.

The Kyoto Protocol stresses domestic emissions reductions and a supplementary role for international credits.[15] Although the plan acknowledges an important role for international permits and credits, the focus of Project Green is also on domestic emissions reductions. It is interesting then that our results show greater domestic reductions in the IPT experiment than are achieved with Project Green. PG's relatively low price cap on permits ($15 per tonne) for large final emitters acts as a significant impediment to GHG emissions reductions at home.

15. See Government of Canada (2007: 12).

TABLE 11 Sectoral Comparison – PG vs IPT

		PG Sectoral Activity (%)	IPT Sectoral Activity (%)
NB	Utilities	-0.32	-0.10
	Mining	-7.02	-14.59
	Manufacturing	0.28	0.62
	Transportation	-2.29	-5.73
QC	Utilities	0.49	1.85
	Mining	0.80	0.78
	Manufacturing	0.10	-0.17
	Transportation	-2.64	-5.21
ON	Utilities	-2.30	-3.55
	Mining	2.40	2.44
	Manufacturing	0.67	0.63
	Transportation	-0.68	-1.20
SK	Utilities	-11.34	-20.95
	Mining	-1.76	20.24
	Manufacturing	-1.51	-9.05
	Transportation	3.00	4.64
AB	Utilities	-8.63	-15.17
	Mining	0.15	3.62
	Manufacturing	-1.69	-5.98
	Transportation	0.99	-0.69

Summary and Conclusions

This paper has evaluated Project Green against two single instrument alternatives, international permit trading and a domestic carbon tax. In many respects, the findings echo some earlier results related to the 2002 plan. For example, our simulations suggest that the aggregate welfare loss is highest with a domestic carbon tax. Of the experiments considered, the domestic carbon tax option leads to the most uneven distribution of welfare costs across provinces and generates dramatic changes in activity levels across sectors.

Some aspects of our results are novel. First, we find the aggregate welfare loss from achieving Kyoto is similar whether the federal government opts for the climate policy package as specified in Project Green or instead opts to incorporate Canada into the international permits market. The distribution of welfare effects across provinces is broadly similar in the two experiments. IPT also yields more GHG emissions reductions at home despite PG's stated focus on domestic reductions. Given that one of the federal government's goals, as stated in CCP was to ensure a reasonable sharing of the burden of achieving Canada's Kyoto target we find it interesting that IPT does so while achieving similar overall welfare effects as PG.

Our simulations of the mix of policies in Project Green confirm that Project Green will have limited effect in terms of domestic GHG emissions reductions. Other studies, notably Jaccard et al (2004) and Jaccard et al (2006), have also questioned the efficacy of the federal government's CCP and Project Green plans. And while aggregate welfare and emissions reductions do not depend much on whether PG is implemented with or without effective transportation measures, transportation measures do affect the distribution of burden across provinces and sectors.

The key contribution of our paper is that the distribution of burden across provinces does indeed depend on the climate change policies undertaken. Alberta and Saskatchewan fare best under a domestic carbon tax and would rank PG over IPT. The Atlantic provinces, Manitoba and BC all prefer Project Green. Ontario fares best with international permit trading and is worse off under PG. Quebec prefers PG or IPT to the domestic carbon tax option. Future work needs to consider the provincial dimension as it clearly plays a critical role in the Canadian climate debate.

There remains a substantial amount of work to be undertaken in this area. As is the case with any CGE analysis, sensitivity to key parameter values is always an issue. Our paper shows that results may also be sensitive to assumptions regarding policy effectiveness. Future work should consider sensitivity of results on this dimension as well.

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