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Fiscal Affairs Department

Canada's Carbon Price Floor

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Abstract

The pan-Canadian approach to carbon pricing, announced in October 2016, ensures that carbon pricing applies throughout Canada in 2018, with increasing stringency over time to reduce emissions. Canadian provinces and territories have the flexibility to either implement an explicit price-based system—with a minimum price of CAN $10 per tonne of carbon dioxide equivalent in 2018, increasing to CAN $50 per tonne by 2022—or an equivalently scaled emissions trading system. This paper discusses the rationale for, and design of, the price floor requirement; its (provincial-level) environmental, fiscal, and economic welfare impacts; monitoring issues; and (national-level) incidence. The general conclusion is that the welfare costs and implementation issues are manageable, and pricing provides significant new revenues. A challenge is that the floor price by itself appears well short of what will be needed by 2030 for Canada's Paris Agreement pledge.

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I. INTRODUCTION[1]

One hundred and ninety countries submitted pledges to reduce carbon dioxide (CO_2) and other greenhouse gases (GHGs) — so-called "Nationally Determined Contributions" (NDCs) — for the 2015 Paris Agreement on climate change.[2] Canada, the ninth largest absolute emitter of CO_2, the fourth largest per capita emitter, with a CO_2 intensity of gross domestic product (GDP) similar to the United States (but well below that of China, India, and South Africa), pledged to reduce GHGs by 30 percent below 2005 levels by 2030, an NDC which is (nominally at least) in line with those of many other Group of Twenty (G20) major economies (Table 1). It is widely recognized among analysts and policymakers[3] that carbon pricing is the most effective instrument for exploiting, and striking the cost-effective balance across, behavioral responses at the firm, household, and sectoral level for reducing CO_2;[4] raises significant revenue; and can be straightforward administratively (e.g., as an extension of existing fuel taxes).[5]

In October 2016, Prime Minister Justin Trudeau proposed a pan-Canadian approach to carbon pricing ensuring that carbon pricing applies throughout Canada in 2018 with increasing stringency over time. Canadian provinces and territories have the flexibility to either implement an explicit price-based system (e.g., a carbon tax like in British Colombia or a carbon levy and performance-based emissions system like in Alberta) or an emissions trading system (ETS), with revenues remaining in the jurisdiction of origin. Jurisdictions with an explicit price-based system should have a minimum price of CAN $10 per tonne of carbon dioxide (CO_2) equivalent in 2018, rising to $50 per tonne — or U.S. $39 per tonne[6]— by 2022. Jurisdictions with ETSs should have: (i) a 2030 emissions reduction target equal to or greater than Canada's 30 percent reduction target; and (ii) declining annual caps to at least 2022 corresponding, at a minimum, to the projected emissions reductions that would otherwise result in that year from a price-based system. The federal "carbon pricing backstop system" will impose pricing of fossil fuel GHGs in any province or territory that requests it or that does not have carbon pricing systems aligned

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[2] Although NDCs are voluntary, countries are required to report progress on meeting them every two years starting in 2018, and to submit revised pledges every five years, which are expected to be progressively more stringent (the United States, however, plans to withdraw from the Agreement by 2020). Prior to ratification of the Paris Agreement in November 2016, submissions were called INDCs, where "I" stood for "intended."

[3] See discussions in Krupnick et al. (2010) and Stern and Stiglitz (2017) and statements at www.carbonpricingleadership.org/carbon-pricing-panel.

[4] CO_2 emissions account for around 70 percent of global GHGs and (on current policies) this share is projected to rise in the future (e.g., UNEP 2016).

[5] See Calder (2015) and Metcalf and Weisbach (2009) for administrative issues.

[6] Unless otherwise indicated, monetary figures are in CAN $.

with the "benchmark" criteria in 2018 or, if needed, supplement them with a "top-up."[7] This policy would establish Canada as one of the most aggressive emission pricing countries — ETS prices elsewhere are around U.S. $15 per tonne or less,[8] while carbon taxes are typically around U.S. $25 per ton or less[9]— Finland, Norway, Sweden, and Switzerland impose substantially higher carbon taxes but rates apply to a minor portion of GHGs.

At the provincial level, carbon taxes have so far been introduced in British Columbia and Alberta,[10] and ETSs in Ontario and Quebec, all with fairly comprehensive coverage of greenhouse gases (GHGs)—principally CO_2—from fossil fuels.[11] Emissions prices for British Columbia and Alberta will be $30 per tonne in 2018, while current prices in Ontario and Quebec are $15–18 per tonne, and revenues are used to lower household and business taxes and fund green energy projects.[12] The federal initiative will therefore increase price levels in these provinces if they fail to meet the benchmark and promote new policies in provinces like Saskatchewan.

This paper is organized as follows. Section II discusses the general rationale for, and design of, Canada's carbon pricing scheme. Section III uses spreadsheet models to: provide a first-pass assessment, for the five largest emitting provinces, of the environmental, fiscal, and economic welfare impacts of carbon pricing; illustrate the potential role of "effective" carbon prices (which account for any non-uniform emissions pricing and fuel taxes); and assess, at the national level, competitiveness and consumer surplus impacts.[13] Some themes of the paper include:

- Coordination over carbon prices, rather than emissions quantities, is generally preferable on economic grounds (e.g., it provides more certainty for mobilizing low-emission investment) and coordination over price floors rather than price levels in principle has some appeal (e.g., jurisdictions where aggressive pricing is more acceptable, or with

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[7] See www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework/guidance-carbon-pollution-pricing-benchmark.html and www.fin.gc.ca/drleg-apl/2018/ggpp-tpcges-eng.asp.

[8] For example, California, the European Union, Korea, and the Regional Greenhouse Gas Initiative in the North Eastern United States (WBG 2017).

[9] For example, Chile, Denmark, Mexico, Finland, France, Ireland, Japan, Portugal, South Africa, and the UK (WBG 2017).

[10] Alongside elements of trading such as use of offsets and a trading system for large emitters based on emission intensity targets. See, for example, www.osler.com/en/resources/regulations/2015/carbon-ghg/carbon-and-greenhouse-gas-legislation-in-british-c.

[11] See Ragan (2017) and WBG (2017).

[12] For example, in British Columbia revenues were used for a 5 percent reduction in the first two personal income tax rates, a low-income tax credit, reductions in the corporate income tax, an industrial property tax credit, and relief for northern and rural homeowners.

[13] For some recent discussion of Canada's carbon price floor see, for example, Bagnoli (2016), Sawyer and Bataille (2016), and Snoddon (2016). Most prior academic literature on carbon pricing in Canada has focused on British Columbia's carbon tax, for example, Harrison (2013), Metcalf (2016), Murray and Rivers (2015), and Pederson and Elgie (2015).

higher fiscal needs from carbon pricing, should not be held back) though any pricing above $50 per tonne is likely to be modest;

- Administrative considerations suggest pricing is most naturally implemented at the point of fuel supply with coverage extended gradually over time as administrative capacity for monitoring other (non-fuel) GHG sources is developed;

- The $50 per tonne carbon price reduces CO_2 emissions[14] by an estimated 16–23 percent below levels (with no pricing or other mitigation measures) in 2022 across provinces, raises significant revenues of 0.5–2.5 percent of provincial GDP, and imposes welfare costs (net of domestic, non-climate environmental benefits) of 0–0.45 percent of GDP;

- Focusing the agreement on effective carbon prices allows provinces greater flexibility, makes transparent “chiseling” on the agreement, and should be practical from a technical perspective; and

- The price requirement by itself would raise production costs significantly, for example, on average, by 5.7 percent for all Canadian exporters and 16 percent for the 10 percent of most vulnerable exporters (though under the federal backstop system, and some provincial schemes, relief for large industrial facilities is provided, for example, through an output-based pricing system).

In short, the net costs of the price floor, and the administrative and monitoring issues seem manageable, and pricing provides a valuable source of revenue. The challenge is that, on the one hand the $50 per tonne CO_2 price appears to fall well short of what would eventually be needed to fulfill Canada’s NDC (by pricing alone), but on the other hand, puts Canada well out in front of other countries (not least the United States). Finally, measures to address the resulting competitiveness concerns involve some compromise with environmental and fiscal objectives.

II. THE RATIONALE FOR, AND DESIGN OF, CARBON PRICE FLOOR REGIMES

A. Rationale

This sub-section briefly discusses the case for coordinating sub-national policies over emissions prices rather than emissions quantities, and for coordinating over price floors rather than price levels.

Price versus Quantities

Policymakers can control emissions quantities *or* emissions prices, given uncertainty over future marginal abatement cost schedules. For example, the emissions price needed to meet a given absolute emissions target may be higher than expected if business-as-usual (BAU) emissions (i.e., emissions in the absence of mitigation policies) are greater than anticipated (perhaps due to

[14] The spreadsheet model focuses on CO_2 emissions from fuel combustion rather than a broader measure of GHGs (expressed in CO_2 equivalent).

faster GDP growth or lower fuel prices) or substituting away from polluting fuels is more difficult (e.g., due to slower than expected progress on clean technologies).

As for most other G20 countries, Canada's NDC specifies an emissions target (Table 1), so it might seem more natural for provinces to be assigned emissions allocations to achieve the national level pledge (in 2030) with confidence. This approach is essentially taken in the European Union (EU) where envisioned policies to reduce GHGs 40 percent below 1990 levels by 2030 include tightening the EU-wide ETS cap (principally covering power generation and large industry) and allocating country-level targets for non-ETS emissions.[15] From the perspective of economic efficiency however, annual CO_2 emissions goals are best met on average over time (with predictable emissions prices) rather than rigidly adhered to on a year-to-year basis (with volatile prices), as in the Canadian approach.

For one thing, for a given cumulative emissions reduction over time, costs are higher under annual emissions targets to the extent short term price volatility (about a long run trend)[16] creates differences in (discounted) incremental abatement costs at different points in time. Expected price volatility under an ETS for the United States is estimated to increase cumulative costs by around 15–20 percent compared with a policy where prices rise annually at the interest rate[17] — a significant (though not dramatic) cost increase.[18]

Likely more important is that uncertainty over long-range emissions prices may deter research into, and deployment of, emissions-saving technologies, many of which (e.g., renewable plants) have high upfront costs and emissions reductions persisting for decades.[19] Emissions price uncertainty also creates uncertainty over prospective carbon pricing revenues, hampering planned use of these revenues.

Price Floor versus Price Level Regimes

Conventional wisdom is that, on cost effectiveness grounds, carbon prices should be uniform across jurisdictions through a harmonized carbon tax or linked ETS. In principle however, there are efficiency and pragmatic reasons why allowing individual jurisdictions the flexibility to price emissions more aggressively than others can make sense.

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[15] Delbeke and Vis (2015). A limited form of price control (the Market Stability Reserve) for the ETS was recently introduced but has limited effectiveness (e.g., Hepburn and Teytelboym, 2017).

[16] For example, futures prices for EU ETS allowances varied between €5 and €30 per tonne between 2008 and 2016 (Farid et al. 2016, Figure 6).

[17] Fell, MacKenzie, and Pizer (2012).

[18] Quantity targets are more suitable than price targets when marginal environmental damages from emissions rise rapidly and it is important to keep emissions below a threshold level (e.g., Weitzman, 1974). This does not apply to global warming because damages depend on the atmospheric stock of GHGs, which has been accumulating since the Industrial Revolution.

[19] UK DECC (2011).

First, a jurisdiction may wish to price carbon higher than the floor price to raise more revenue from an easily collectible source — and this can be economically efficient.[20]

Second, it can also be more efficient for one jurisdiction to set higher emissions prices than in other jurisdictions if this generates larger local environmental benefits, like reductions in air pollution deaths.[21]

Third, the political acceptability of carbon pricing differs across jurisdictions (e.g., British Columbia and Quebec have been pricing emissions since 2008 while Saskatchewan has so far opposed pricing) and a price floor does not hold back provinces that might be willing and able to price emissions more aggressively (perhaps because the province wants to be an environmental leader).

In fact, carbon price floors have an analog from arrangements designed to provide some degree of protection against tax competition in trading blocs. For example, in the EU there are tax minima for value added taxes and excises on alcohol, tobacco, and energy products (though member states routinely set rates above the minima).[22]

All these arguments, however, are more compelling for a pricing agreement among countries with considerably different fiscal needs, local environmental impacts, and green preferences. In contrast, there is only limited heterogeneity among Canadian provinces in the sense that they are generally able to raise sufficient revenues from broader fiscal instruments (unlike, for example, an emerging market economy with a large informal sector); limited use of coal implies limited local air pollution benefits from carbon pricing; and even a province concerned about its environmental reputation may be unwilling price CO_2 emissions much in excess of $50 per tonne, due to competitiveness concerns if other countries (notably the United States) are not following suit.

B. Implementation

This subsection discusses design issues for price floors including emissions coverage, administration, choice of pricing instrument, price levels, and monitoring.

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[20] Traditionally, it was thought that carbon taxes were a less efficient source of revenue (not counting environmental benefits) than taxes with a much broader base like personal and payroll taxes, implying efficient taxes are (moderately) below levels warranted on environmental grounds alone (e.g., Bovenberg and de Mooij, 1994). However, this finding does not necessarily apply when the full range of distortions beyond those in factor markets created by broader taxes are considered (e.g., the bias towards informal activity and tax-sheltered spending like housing and fringe benefits), as this can substantially increase the efficiency gains from recycling carbon tax revenues in broader tax reductions (e.g., Parry and Bento, 2000).

[21] Parry, Veung, and Heine (2014), for example, estimate quite divergent local environmental benefits from carbon pricing across different countries.

[22] In the tax competition literature, tax floors that raise rates for low tax countries can also benefit countries where the floor is not binding by limiting the international mobility of the tax base and enabling them to set higher taxes (see, for example, Kanbur et al. 1995 for some discussion in an environmental context).

Coverage

Although the carbon pricing requirement applies to all ten Canadian provinces (and three territories), five provinces accounted for 93 percent of national GHGs of 720 million tonnes in 2014 (Figure 1) — Alberta (38 percent), Ontario (28), Quebec (11), Saskatchewan (10), and British Columbia (8) — while the sixth largest emitter Manitoba accounted for just 3 percent of emissions. For practical purposes, therefore, it is these five provinces for which carbon pricing is especially important (and which are the focus of the analysis here) and, as noted, four of them have already introduced carbon pricing. The emissions intensity varies considerably, from a low of 0.21 tons of GHGs per CAN $1,000 GDP in Quebec to 1.05 in Saskatchewan in 2014 (Figure 1), implying significant differences in carbon pricing costs and revenues relative to GDP (as discussed later).

CO_2 emissions from fossil fuel combustion vary between 62 percent (Saskatchewan) and 73 percent (Alberta) of total GHGs across provinces. The remainder reflect some combination of: (i) a small amount of methane and nitrous oxide from fossil fuel combustion; (ii) fugitive emissions (e.g., leaks of CO_2 used in enhanced oil recovery); (iii) process emissions (e.g., use of clinker in cement manufacturing); and (iv) non-combustions sources of non-CO_2 GHGs (e.g., methane leaks from oil and gas fields and agricultural activities).[23] Fossil fuel combustion emissions (CO_2 and non-CO_2 GHGs) are the most straightforward to monitor and price (e.g. these emissions are covered by existing pricing schemes in British Colombia, Alberta, Ontario and Quebec[24]). Clinker production can be monitored (along with its lime content) and a tax imposed in proportion to clinker emissions factors.[25] Methane and nitrous oxide have high global warming potentials[26] and in principle would be a relatively low-cost mitigation option. Methane leaks from oil and gas field operations could be measured by detectors (e.g., on vehicles) and a charge should be feasible and effective (the problem is often a small number of large leaks some of which might be fixable with only a wrench). Pricing agricultural methane and nitrous oxide is administratively challenging however,[27] and these emissions are sometimes included through offset provisions.[28]

[23] EC (2017) provide data on all these emissions sources for Canadian provinces.

[24] Industrial process emissions are also covered in the last three cases.

[25] See IPCC (1996) for comprehensive guidance on emissions factors.

[26] A ton of methane and nitrous oxide are equivalent to 21 and 310 tons, respectively, of CO_2 in global warming equivalents over a century according to US EPA (2014).

[27] Methane emissions primarily come from digestive processes of cows and sheep and, although a tax could be imposed per head (perhaps with reduced rates for lower emitting animal types and where there was proof of emissions-reducing diets), this would be administratively complicated. Much of the nitrogen oxide emissions also come from agricultural sources (soil, fertilizer practices, etc.) but again these sources may be impractical to tax (alternative approaches such as taxing fertilizer inputs could be explored, though there might be a risk of unintended consequences, like inducing a shift from crops to livestock).

[28] Ideally, international offsets (where provincial entities in Canada can pay for mitigation projects in developing countries and credit the resulting emissions reductions against tax or permit requirements for their own emissions) would be precluded from a price floor. Not least, there is the considerable practical challenge of

Carbon Price Administration

A carbon tax is straightforward to collect through charges on fossil fuel supply (which is already measured as part of normal business procedures) in proportion to their CO_2 emissions factors (which are well established, per unit of volume for petroleum products and per unit of energy for coal and natural gas).[29] From an administrative perspective, collecting the tax after processing (i.e., after crude oil is distilled, gas is separated from water and impurities, and coal is washed to remove rocks and dirt) has some appeal over collecting it at the point of extraction as carbon emissions factors are slightly more accurate for processed fuels and the number of collection points is very small[30] reducing opportunities for avoiding measurement. Fuel imports (from other countries or provinces) should be taxed and fuel exports exempt (as provinces are accountable for fuel combustion emissions within their borders).

In contrast, imposing carbon pricing downstream at the point of fuel combustion is generally less comprehensive, as these schemes are typically imposed (for administrative reasons) only on installations with emissions above a threshold (e.g., 25,000 tonnes of CO_2 per year) and need to be combined with upstream pricing of fuels used in vehicles and buildings. Such schemes can also impose greater administrative burdens as downstream businesses are required to measure their fuel inputs or emissions. An element of downstream pricing is needed, however, to cover process emissions.

Choice of Pricing Instrument

Carbon taxes are usually imposed on fuel suppliers and comprehensively cover combustion emissions, while ETSs (e.g., in the EU) have often been limited to downstream large fuel users—but in principle there is no reason ETSs cannot also be applied to suppliers of fuels (e.g., for transport and homes) that would otherwise be exempt (as is the case in the Ontario and Quebec ETSs).

Beyond administrative issues, carbon price floor requirements are more naturally met through carbon taxes. There are various options however, for accommodating ETSs. One is to combine them with an explicit price floor mechanism, such as a minimum biding price at auction. Another is to combine the ETS with a variable carbon tax where the tax rate equals any prevailing

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verifying that offsets actually reduce emissions (i.e., that the project would not have gone ahead anyway, without the offset) and offsetting reduces provincial revenues by eroding the base on which carbon pricing revenue is collected.

[29] Emissions factors for the non-CO_2 GHGs from fuel combustion are included in the existing provincial pricing schemes and the federal backstop after converting them to CO_2 equivalent (e.g., ECCC 2017b), though this makes only a modest difference to the fuel charge.

[30] For example, Quebec has 2 refineries, Ontario 4, Saskatchewan 4, Alberta 9, and British Columbia 2. Some gas may bypass processing and be fed directly into the pipeline distribution system, and coal may go straight from the mine mouth to the power plant, but such fuel use should be taxable at an alternative upstream point. See Calder (2015).

difference between the floor and current ETS price.[31] And another—as in the Canadian scheme—is to set provincial emissions caps equal to the predicted emissions that would have occurred if the province had adopted a carbon tax in line with the price requirement. A complication here however is that ETSs in Ontario and Quebec are linked to the Western Climate Initiative which includes the large California market, thereby dampening emissions prices in these provinces even if their emissions caps comply with Canadian requirements. In turn, this may lead to significant divergences in emissions prices across linked and non-linked provinces.

Price Level

The economics literature has largely focused on two alternative notions of appropriate carbon prices at the global level, both of which yield prices that are far from the current global average price of about $1 per ton of CO_2.[32] One involves estimating discounted damages (e.g., to agriculture, from rising sea levels, ecological disruption, more extreme climate risks) from the future climate change induced by higher atmospheric GHG concentrations resulting from current emissions which, for example, US IAWG (2017) estimate (though not without controversy) at about US $50 per ton for 2020 emissions (in 2015$) in their central case, rising at about 2–3 percent a year in real terms. The other approach involves estimating price trajectories consistent with future climate stabilization (ideally with lowest cost), for example, containing mean projected warming to 2^{o}C (the official, though highly challenging, goal of the Paris Agreement) would require carbon prices of at least US$40–80 per ton by 2030 and $50–100 by 2030.[33]

In light of the Paris Agreement, however, the more immediate concern for policymakers is implementing prices in line with their mitigation pledges (Table 1), which requires country-level projections of fuel use and the future responsiveness of fuel use to carbon pricing. Based on the analysis below, Canada's $50 per tonne price floor for 2022 seems reasonable as an intermediate target, though for competitiveness reasons further floor price increases beyond 2022 (needed to meet Canada's Paris pledge for 2030) may hinge on pricing developments in trading partners.

Monitoring Issues

A potentially significant issue for intra-jurisdictional carbon pricing regimes is that (e.g., for administrative or political reasons) certain emissions sources may be subject to favorable (or zero) prices and, moreover, the impacts of a direct carbon price might be partially offset (or enhanced) by changes in pre-existing fuel taxes. Focusing the agreement on "effective" carbon prices, which account for both these factors, would allow provinces flexibility in meeting the floor (e.g., they could implement differentiated pricing so long as lower prices for favored sources are compensated by higher prices elsewhere and emissions implications of fuel tax adjustments

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[31] This scheme is currently operating for power generation emissions in the United Kingdom, where the tax (out to 2021) is set equal to the difference between £18 ($32) per tonne and the EU ETS emissions price, currently €5 (£4 or $7.5) per tonne (e.g., Ares and Delebarre 2016).

[32] Authors calculations using WBG (2017).

[33] Stern and Stiglitz (2017).

would be counted).[34] It would also make "chiseling" on the agreement transparent, by indicating to what extent effective carbon prices may have been reduced through lower fuel taxes. The measurement of effective carbon prices in the Canadian context is discussed later.

III. Provincial Level Impacts of Carbon Pricing

This section briefly describes, and presents results from, a simple analytical model, solved in a spreadsheet, for obtaining a first-pass assessment of the environmental, fiscal, and economic welfare impacts of carbon pricing at the provincial level and uses the model to illustrate how effective carbon pricing might be operationalized. A quick assessment of the incidence of carbon pricing at the national level in Canada is also presented.

A. Analytical Model

An analytical model similar to the one used here has been previously applied to carbon pricing (and other policies) in China and India and the reader is referred to those studies[35] for mathematical specifics and typical parameter assumptions (e.g., for fuel price responsiveness and rates of technological change).

The model distinguishes use of coal, natural gas, and a non-carbon fuel aggregate in power generation; gasoline and diesel use in road transport; and direct use of coal, natural gas, and oil in the household and industrial sector (including non-road transport). Provincial fuel use by sector is aggregated from 2014 data in NEB (2016) and projected forward to 2022 in a BAU case using (i) provincial projections of annual GDP growth (between 1 and 2 percent, again from NEB 2016), (ii) income elasticities for the energy products (between 0.6 and 0.7), (iii) rates of autonomous technological change for energy efficiency (0.5 percent a year for fossil generation, 1.25 percent for zero-carbon generation, and 0.75 percent in other sectors), and (iv) future fuel prices (based on averaging over flat price forecasts in IMF 2017 and rising forecasts in IEA 2016). Fuel taxes, and markups over crude prices (e.g., for processing and transportation), are fixed in real terms.

The impact of carbon pricing on fuel use depends on various (constant) elasticities, which are set at –0.5 (a typical mid-point range used in the literature) for use of gas and petroleum products in the road transport and household/industrial sectors (with half the response reflecting improvements in energy efficiency and the other half reductions in product use). The price elasticity for electricity is also set at –0.5, and fuel substitution elasticities within power

[34] Including the carbon price equivalents from quantity-based regulations (e.g., requirements for energy efficiency or renewables) in definitions of effective carbon pricing is probably not advisable. The implicit prices would need to be estimated (by first comparing observed outcomes with those from a counterfactual where regulations do not bind and then assessing the pricing analog that would have the same effect as the regulation). Moreover, these regulations overlap with carbon pricing and (to avoid double counting) only the excess response above that promoted by the carbon price should be counted. Royalties on fossil fuel extractives should probably not be included either as (given Canada is largely a price taker in international fuel markets) these are mostly passed back to fuel producers rather than passed forward into higher prices for provincial fuel users.

[35] See the model descriptions in Parry et al. (2016) and Parry, Mylonas, and Vernon (2017), respectively.

generation are chosen such that (conditional) coal and gas demand elasticities are –0.5 and –0.75, respectively.

User prices for gasoline and diesel vary modestly across provinces due to differences in provincial excises, while prices for coal, natural gas, and other petroleum products are taken as a given across provinces. Carbon pricing raises fuel prices in proportion to the fuel's CO_2 emissions factors (account is not taken here of pricing for other GHGs from fuel combustion).[36] Delivered electricity prices[37] for 2014 vary between 7.3 (in Quebec) and 14.5 (in Alberta) cents per kWh, and these prices change in the future with changes in generation costs (which vary with technological change, international fuel prices, and carbon price-induced fuel price increases) for particular fuels (weighted by the fuel's share in total generation). Any current carbon pricing in a province is set to zero in the BAU case (with BAU fuel use rising correspondingly) and each province is then assumed to implement a $50 per tonne carbon price, where the carbon price applies comprehensively across fossil fuel CO_2 emissions—this provides a clean comparison across provinces.[38]

The focus is on CO_2 emissions (rather than GHGs more broadly), and the impacts of carbon pricing on these emissions are easily calculated from the changes in fuel use and carbon emissions factors. Revenue calculations account for changes in the bases of provincial level fuel taxes, but not broader taxes on businesses and firms (that might be indirectly affected through changes in economic activity) nor federal level taxes. Economic welfare costs are calculated using extensions of standard formulas (for changes in consumer and producer surplus in fuel markets) in public finance, accounting for prior fuel tax distortions[39] and costs are also calculated net of domestic externality benefits (e.g., reductions in local air pollution deaths, traffic congestion) using (updated) national-level estimates of these externalities for Canada.[40]

Clearly the analysis is highly simplified, for example, there are no trade linkages among provinces or other countries, and the model does not distinguish capital of different vintages. From basic principles of public finance however, for a given long-run impact on fuel use, fuel taxes, and unit environmental costs, the environmental, fiscal, and economic welfare impacts of carbon pricing predicted by the simplified, reduced form model should be approximately consistent with those predicated by a much more detailed structural model. A more important caveat (discussed later)

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[36] The analysis focuses only on CO_2 emissions whereas pricing will be applied to a broader range of GHGs from fuel use—this leads to a modest understatement of emissions, revenue, and welfare impacts.

[37] From Goulding and Atanasov (2014).

[38] In practice in ETS systems the carbon price will be determined by the market in response to the cap, and should be approximately in line with $50 per tonne in unlinked systems, but potentially less than that in systems linked to US trading markets. More generally, there are exemptions to carbon pricing, for example, in British Colombia farm use of diesel fuel is not subject to carbon taxation (see www2.gov.bc.ca/gov/content/taxes/sales-taxes/motor-fuel-carbon-tax/business/exemptions).

[39] Harberger (1964) provides a discussion of these formulas

[40] These are taken from the extensive cross-country assessment in Parry et al. (2014).

is that the analysis does not account for provisions for large industry which might significantly lower the fiscal and environmental effectiveness of carbon pricing. Key parameters determining BAU projections, and the responsiveness of fuel use to carbon pricing, are uncertain (depending, for example, on how fast it advances clean technologies), though, loosely speaking, the sensitivity of results to alternative assumptions is intuitive (e.g., increasing fuel price elasticities by 50 percent would increase emissions reductions and welfare costs of carbon pricing by roughly 50 percent).

B. Results

According to the BAU projections (with zero carbon pricing in all provinces), the household/industrial sector accounts for more than half of projected CO_2 emissions in 2022, mostly from natural gas (Figure 2). The power sector accounts for more than 20 percent of BAU emissions in Alberta and Saskatchewan, where coal use is significant, but for less than 2 percent in British Columbia and Quebec, which use a lot of renewables. Road fuels account for between 11 percent of emissions in British Columbia and 44 percent in Quebec.

As indicated in Figure 3, the $50 per tonne carbon price (imposed against the counterfactual with no carbon pricing or mitigation measures) would increase the price of coal by 126 percent, natural gas 100 percent, road fuels about 20 percent, and other oil products (not subject to excise) by 37 percent (these figures are for Alberta but would be largely the same for other provinces). Per unit of energy, the fuel price increases are not as dramatically different — between $2.8 per gigajoule (GJ) for natural gas to $4.8 per GJ for coal — but the proportionate price increases for road fuels are not that large as they build on top of pre-existing prices (inclusive of $5 per GJ fuel taxes) that are almost five times larger per GJ than for coal. Also noteworthy is that (rough estimates of) non-carbon externalities (principally congestion and accidents rather than local air pollution) from road fuels are much larger, at around $17 per GJ, than the combined fuel taxes and carbon charges, so to the extent CO_2 emissions come from reduced use of road fuels there is a net economic benefit (without even counting global climate benefits). Although there are some air pollution benefits from reducing coal and natural gas they are smaller per GJ, especially for gas, than the carbon charge, so to the extent CO_2 reductions come from these fuels there is still a net cost, despite the domestic environmental benefits.

The $50 per tonne carbon price reduces CO_2 emissions below BAU levels in 2022 by between 16 percent in Quebec and 23 percent in British Columbia and Ontario (Figure 4a), or by roughly half of the nationwide emission reduction of 42 percent that would be needed if Canada's Paris pledge (of limiting emissions to 30 percent below 2005 levels) were applied in 2022.[41] The CO_2 reduction is smallest in Quebec given its large share of road fuels in total emissions and the relatively modest proportional price increases for these fuels.

Carbon pricing in 2022 would raise substantial amounts of revenue — around 0.5 to 1 percent of GDP in Quebec and Ontario and around 2.0–2.5 percent of GDP in the other provinces (Figure

[41] In fact, a CO_2 price of around $170 per ton would be needed to meet the Paris pledge, according to the spreadsheet, though this estimate is highly speculative, not least because fuel price responsiveness may be substantially greater for dramatically higher carbon prices (that might incentivize radical technological change).

4b), with these differences mainly reflecting differences in the CO_2 intensity of GDP. Carbon pricing does erode the revenues from pre-existing road fuel taxes, but this effect is very modest, given the relatively small share of road fuels in CO_2 reductions.

The economic welfare costs of carbon pricing (approximated by trapezoids in road fuel markets with prior taxes and triangles in other fuel markets) vary from 0.15–0.3 percent of GDP in Quebec and Ontario to more than 0.6 percent of GDP in the other, more emissions intensive, provinces (Figure 4c). These costs are significant, however subtracting the domestic environmental benefits (reductions in air pollution deaths, traffic congestion, etc.) the net welfare losses are reduced by around one-third (in Alberta and British Colombia) to one-half (in Saskatchewan) or more (Quebec and Ontario, where road fuels, which have the highest external costs, account for a larger share of CO_2 reductions).

C. Effective Carbon Prices

In deriving measures of effective carbon prices when emissions pricing is non-uniform, or fuel taxes are changing, it is important —though conceptually straightforward— to account for the relative environmental effectiveness of these provisions.

For example, suppose, for whatever reason, road fuels are exempt from carbon pricing. The effective carbon price would be lowered by the share of road fuels in the CO_2 reductions that would have occurred under comprehensive pricing, rather than the projected share of road fuels in BAU CO_2 emissions. This distinction is important, for example, for Quebec, where the reduction in the effective carbon price would be 20 percent (from Figure 4a) rather than 44 percent (from Figure 2).

And similarly, the implications of changes in gasoline and diesel fuel taxes for effective carbon prices can be computed by converting them into changes in carbon price equivalents multiplied by the share of gasoline and diesel in the CO_2 reductions under uniform carbon pricing (from Figure 4a). Using the spreadsheet model, this implies a 25 percent reduction in fuel taxes in 2022 would lower the effective carbon price by between only \$0.5 and \$1.5 per tonne of CO_2 in four provinces. In other words, these (quite significant) fuel tax reductions are not very important for the effective carbon price (relative to the required \$50 per tonne 2022 price). For Quebec, the 25 percent fuel tax reduction lowers the effective carbon price by somewhat more, \$4 per tonne (due to the relatively high share of road fuels in CO_2 reductions from Figure 4a) so tracking changes in fuel taxes is a little more important in this case.

D. Incidence Analysis

Industry Incidence

The (national-level) industry incidence of carbon pricing was calculated using the 2013 (most recent) input-output table for Canada, published by Statistics Canada (the national statistical authority), and which disaggregates 230 sectors. For each industry, potential inputs include coal, natural gas, oil, and electricity. Price increases for 2022 are taken from the spreadsheet (with increases in electricity prices based on a population-weighted average of increases at the provincial level). Impacts of higher input prices on industry output prices or unit costs are calculated assuming the same energy input shares and output prices for 2022 as for 2013 and full pass through of input costs into output prices. This overstates somewhat the output price increases, for example, to the extent future energy input shares decline in response to carbon pricing or other mitigation measures, and (more importantly) it does not account for special provisions (noted above) for trade-exposed industries.

Figure 6(a) indicates the estimated percent increase in costs in 2022 for the 20 industries that would be most affected by a (pure) carbon price floor, collectively representing 7 percent of total output. Cost increases are significant, varying from 9.4 percent in diamond mining, to 12.5 percent in forestry and logging, to 23.2 percent in water transportation.

Cost increases from pure carbon pricing would be more sensitive for industries reliant on exporting to other countries, especially countries (like the United States) not taking significant mitigation actions. Figure 6(b) provides an indication of international competitiveness impacts by plotting the relation between the export share-weighted average (percent) cost increase and the cumulative share of exports. For example, for the 10 percent of most affected exporting industries, the average cost increase due to carbon pricing in 2022 is 16.6 percent, for the 32 percent of most affected exports the average cost increase is 9.9 percent, and for exporters as a whole, the average cost increase is 5.6 percent.

In short, competitiveness impacts under a pure pricing scheme would be significant (at least until competitor countries implement comparable carbon pricing). This issue would be addressed for provinces subject to the federal backstop system through allowing large industry (facilities emitting 50,000 tonnes or more of CO_2) to participate in an output-based pricing scheme where they are effectively charged (at $50 per tonne) for their marginal emissions but not their infra-marginal emissions, that is, they are charged on any emissions in excess of a GHG emissions limit and receive tradeable credits if their emissions are below the limit.[42] This system imposes a substantially smaller burden on industry than direct carbon pricing would (as there is no first-order tax payment or ETS allowance rent reflected in higher product prices) at the expense of being less environmentally effective (it preserves incentives to reduce emissions per unit of output but not to reduce the overall level of output) and foregoing revenue.

Household Incidence

Budget shares for main categories of household consumption goods were calculated at the national level from the 2009 Survey of Household Spending (also provided by Statistics Canada

[42] The proposed limit is given by their output times 70 percent of the production-weighted national average emissions intensity for the industry classification (facilities emitting between 20 and 50 kilotons of CO_2 equivalent, and undertaking/producing an activity/product for which an output-based standard has been prescribed, can opt into the system). Alberta is the only province so far to have adopted this type of output-based pricing scheme (for facilities emitting 100,000 tonnes or more of CO_2). Ontario and Quebec instead provide free allowance to some industrial facilities.

and covering 16,758 households).[43] Direct consumer surplus losses from higher prices for household energy products were obtained by multiplying the price increases (generated by the spreadsheet) by the corresponding budget shares for these products. Indirect consumer surplus losses from the increases in prices of other consumer goods (resulting from higher energy costs for producing these goods) are estimated (assuming full pass through) using the 2013 input-output table (see section D.1.) multiplied by the corresponding household budget share. Budget shares and input/output ratios are taken to be the same in 2022 as in the years of the household survey and input output tables. This approach (moderately) overstates incidence impacts in the sense that it ignores behavioral responses to carbon pricing (that lower household demand for energy intensive products and the energy intensity of production), and the infra-marginal emissions exemptions for large industry.

Overall, the $50 per tonne carbon price is, roughly speaking, distribution neutral—burdens vary from 6.8 percent of consumption for the second decile to 7.8 percent for the sixth decile (Figure 7). The direct burden of higher energy prices accounts for around 50-60 percent of the total burden of carbon pricing and the relative disparities across households are somewhat more pronounced, though without a clear pattern (burdens for the bottom and top consumption decile, for example, are 3.3 and 3.9 percent of consumption respectively). The burden from the indirect increase in prices of other consumer products is more evenly distributed varying only between about 3.2 and 3.6 percent of consumption across different deciles. Compensating the bottom decile for the loss in consumption would require only 5 percent of potential carbon pricing revenues (12 percent for the bottom two deciles).

IV. Conclusion

The administration, monitoring, and net costs (at least to 2022) of Canada's carbon price floor seem manageable,[44] though whether the carbon price can be aggressively ramped up after 2022 (to meet the 2030 Paris pledge) is questionable and will depend in part on mitigation actions in other countries (not least the United States).

From an international perspective, Canada's carbon price floor could provide a valuable prototype for how an analogous scheme might be applied to a coalition of large emitters as a complement to the Paris process. As noted, the case for a price floor (as opposed to a uniform price) regime is more compelling at the country group level, given greater heterogeneity in fiscal needs, domestic environmental benefits, and political acceptability of pricing. Enforcement (i.e., deterring countries from reneging on carbon pricing) is the key difference as (unlike in the Canada case) there is no supranational authority that can step in and impose pricing on non-

[43] Given that consumption expenditure better encompasses lifetime income then annual income (Poterba, 1991), we divide households into consumption deciles (the first decile being the poorest and the tenth being the richest).

[44] Some caveats might include: (i) some provinces may still want to negotiate with the federal government about how exactly they implement carbon pricing; (ii) Canada lacks climate governance infrastructure, including national stocktaking and carbon budgeting processes, and governments and industry have yet to agree on coordinated policies; and (iii) there are challenges in implementing abatement measures consistently across jurisdictions. See, for example, Bagnoli (2016), Sawyer and Bataille (2016), and Snoddon (2016).

compliant countries. However, by recognizing internationally traded mitigation units, Article 6.2 of the Paris Agreement provides a potential vehicle for encouraging broad participation: countries with less stringent NDCs can gain from exceeding their pledges and selling the excess mitigation units at the floor price, while countries with more stringent NDCs can benefit from purchasing mitigation units from other countries at the floor price to meet their mitigation requirements at lower cost.

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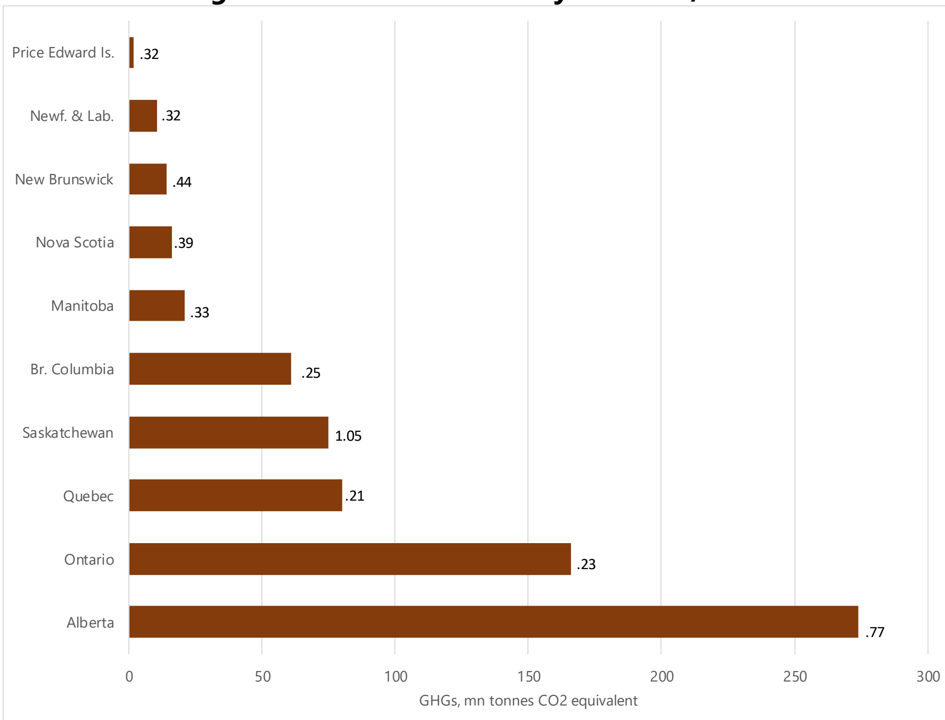
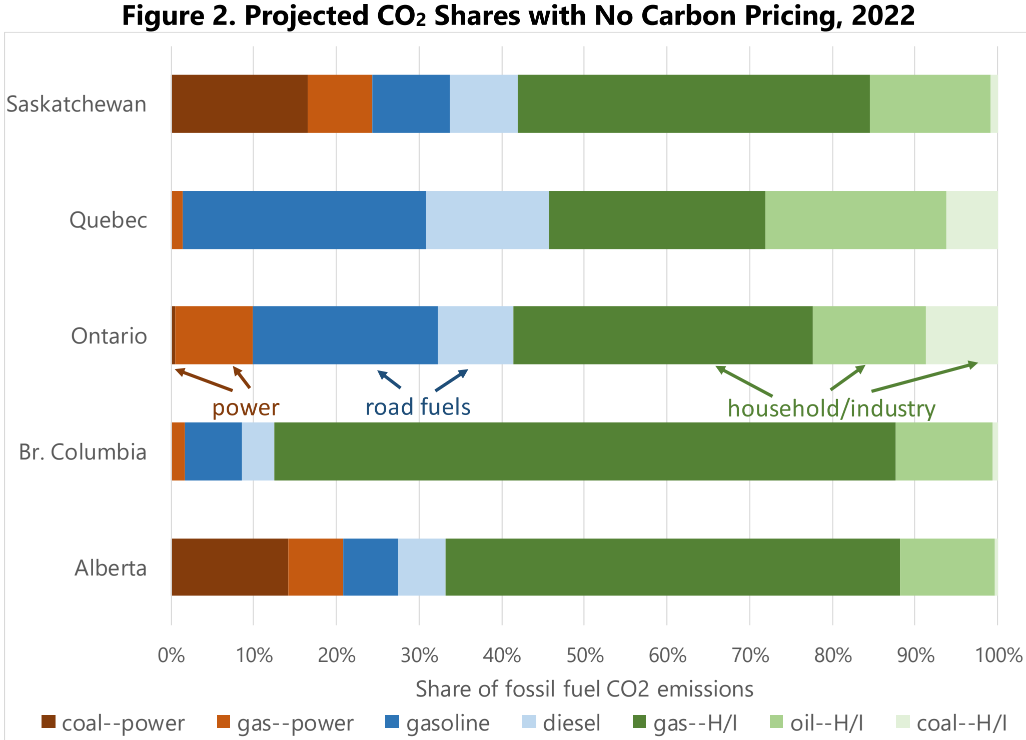
Figure 1. Sources of GHGs by Province, 2014



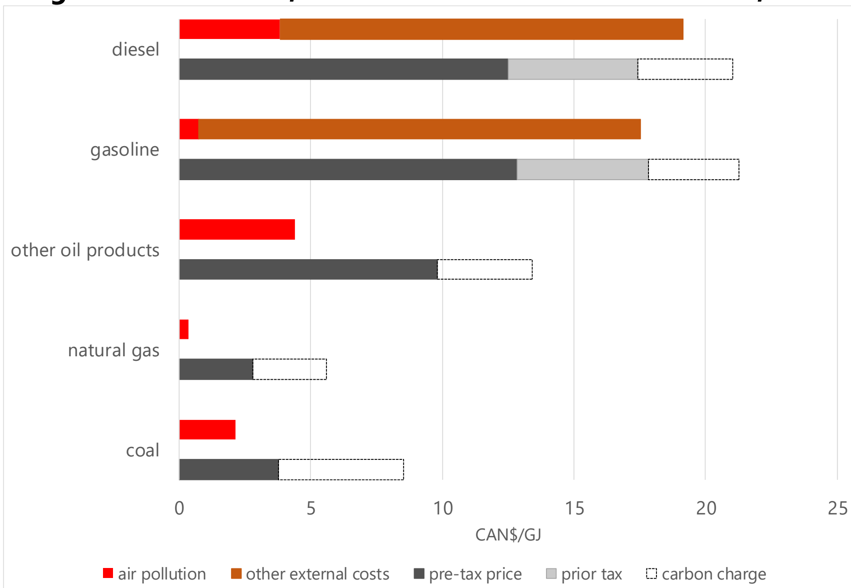
Source: ECCC (2017b), Table S4, NEB (2016).
Note: Figures at the end of the bars indicate GHG emissions per CAN $1,000 of GDP. GHG emissions from Canada's three territories were 2 million tonnes.

Figure 2. Projected CO_2 Shares with No Carbon Pricing, 2022



Source: See text

Figure 3. Fuel Prices, Taxes and Externalities for Alberta, 2022

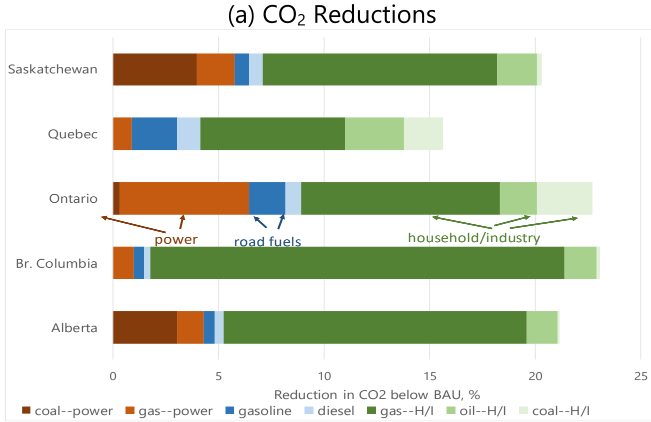


Source: See text.

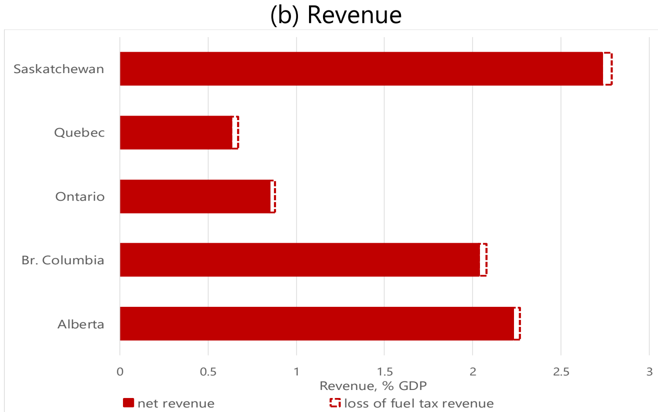
Note: Figures are the same as above for other provinces aside from the prior road fuel taxes. The prior tax refers only to the provincial excise (not general sales tax which raises the price of consumer products in general).

Figure 4. Impacts of $50 Carbon Price, 2022

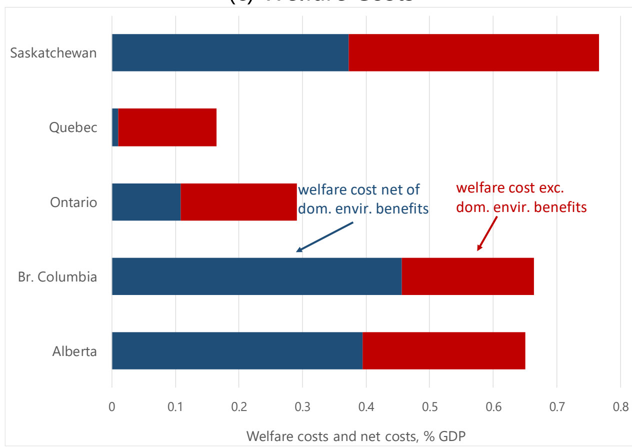
(a) CO_2 Reductions



(b) Revenue



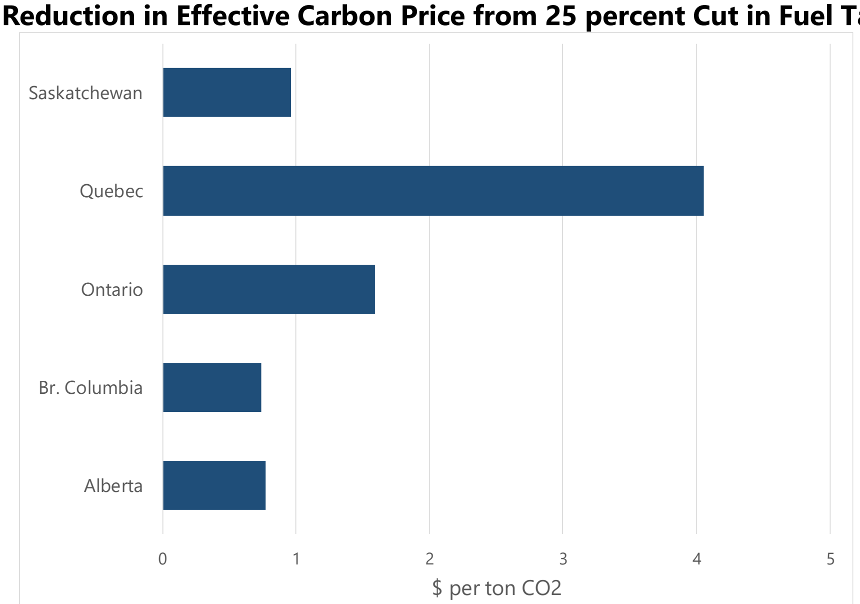
(c) Welfare Costs



Source: See text.

Note. The carbon price applies comprehensively across fossil fuel emissions with no special provisions (e.g., for trade-sensitive sectors) and impacts are relative to a baseline with no carbon pricing. Welfare impacts do not account for global climate benefits or linkages with the broader fiscal system (e.g., from recycling revenue).

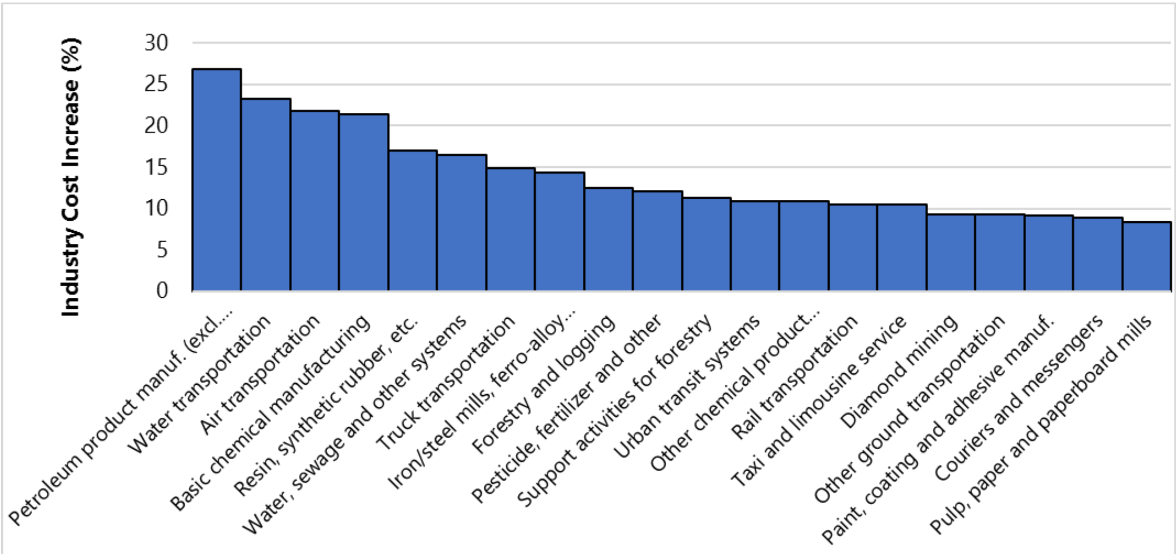
Figure 5. Reduction in Effective Carbon Price from 25 percent Cut in Fuel Taxes, 2022



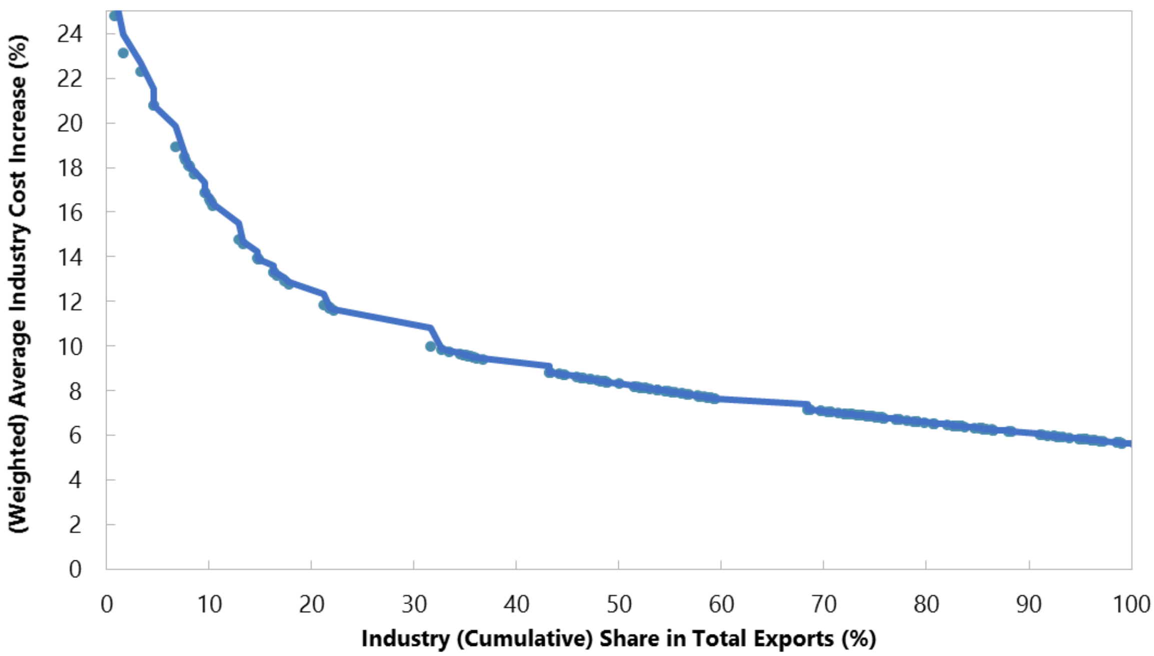
Source: See text.

Figure 6. Impacts of $50 Carbon Price on Industry Costs, 2022

(a) Percent Cost Increases for Most Vulnerable Industries



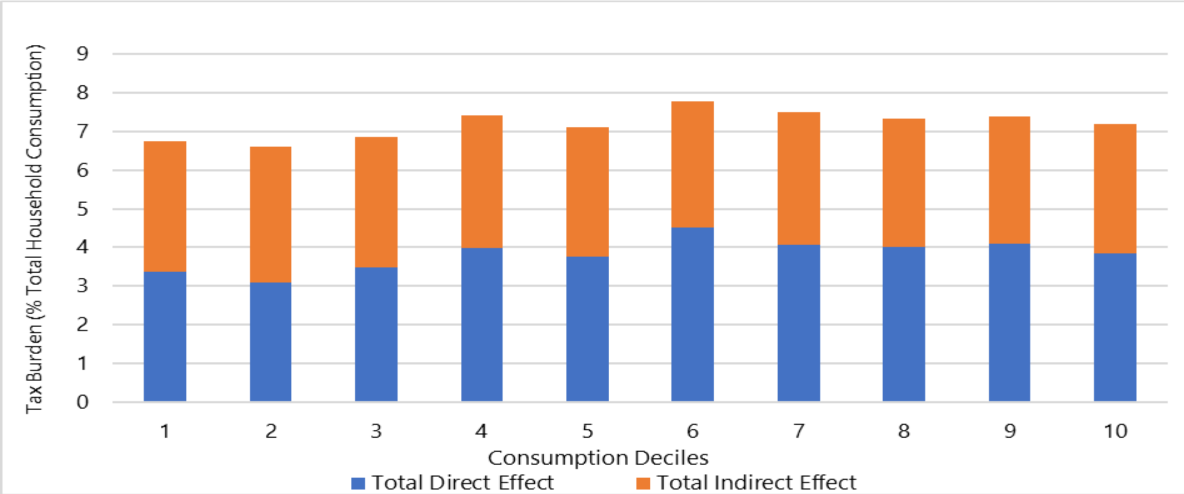
(b) Cumulative Average Costs Increases for Exporting Industries



Source: See text. Note: Panel (a) shows 20 industries that incur highest cost increases.

Figure 7. Total Burden of $50 Carbon Price on Household Consumption Deciles, 2022

(Percent of Household Consumption)



Source: See text.

Note: Households are grouped into deciles per their total consumption as reported in the 2009 Survey of Household Spending, where the first and tenth deciles are the lowest and highest consumption groups respectively.

Table 1. NDCs for the Paris Agreement, G20 Countries

Country	Mitigation Pledge: Reduce…	2014		
		Share Global CO_2	Tons CO_2/US$mn GDP	Tons CO_2/ capita
Argentina	GHGs 15% below BAU in 2030	0.6	0.39	4.7
Australia	GHGs 26–28% below 2005 by 2030	1.0	0.25	15.4
Brazil	GHGs 37% below 2005 by 2025	1.5	0.22	2.6
Canada	GHGs 30% below 2005 by 2030	1.5	0.30	15.1
China	CO_2/GDP 60–65% below 2005 by 2030	28.5	0.98	7.5
France	GHGs 40% below 1990 by 2030	0.8	0.11	4.6
Germany	GHGs 40% below 1990 by 2030	2.0	0.19	8.9
India	GHG/GDP 33–35% below 2005 by 2030	6.2	1.10	1.7
Indonesia	GHGs 29% below BAU in 2030	1.3	0.52	1.8
Italy	GHGs 40% below 1990 by 2030	0.9	0.15	5.3
Japan	GHGs 25% below 2005 by 2030	3.4	0.25	9.5
Korea	GHGs 37% below BAU in 2030	1.6	0.42	11.6
Mexico	GHGs 25% below BAU in 2030	1.3	0.37	3.9
Russia	GHGs 25–30% below 1990 by 2030	4.7	0.83	11.9
South Arabia	GHGs 130 mn tons below BAU by 2030	1.7	0.79	19.5
South Africa	GHGs 398–614 mn tons in 2025 and 2030	1.4	1.40	9.0
Turkey	GHGs up to 21% below BAU by 2030	1.0	0.37	4.5
United Kingdom	GHGs 40% below 1990 by 2030	1.2	0.14	6.5
United States	GHGs 26–28% below 2005 by 2025	14.5	0.30	16.5

Source. UNFCCC (2016), https://data.worldbank.org/indicator.

Note. BAU denotes business as usual with no new mitigation measures. Some countries specify both conditional (contingent on external finance) and unconditional (not contingent) pledges—in these cases the conditional pledges are included above. The United States announced its withdrawal from the Paris Agreement in May 2017.