Report 366
June 2023

An investigation into the effects of border carbon adjustments on the Canadian economy

Y.-H. Henry Chen, Hossein Jebeli, Craig Johnston, Sergey Paltsev and Marie-Christine Tremblay

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—Ronald G. Prinn,
Joint Program Director

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An investigation into the effects of border carbon adjustments on the Canadian economy

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Abstract: This paper examines how border carbon adjustments (BCAs) may address the unintended consequences of uncoordinated global climate action, focusing on the economic implications for Canada. We investigate these implications under different BCA design features and by considering a coalition of countries and regions that adopt BCAs. We find that BCAs, in the form of import tariffs, reduce Canada's carbon leakage to the rest of the world and improve its domestic and foreign competitiveness when Canada is part of a coalition of countries and regions that implement BCAs that includes the United States. We show that these results may change if Canada imposes BCAs on a different set of sectors than the rest of the coalition or includes export rebates and free emissions allowances to firms. When the United States is not part of the coalition, we show that Canada's carbon leakage increases, domestic competitiveness dampens, and foreign competitiveness improves. Compared with a case where no countries have BCAs, welfare improves in Canada if revenues from BCAs, in the form of import tariffs, are transferred to households. This finding holds regardless of the United States' participation in the coalition.

This report is also available at the Bank of Canada website.

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1. Introduction

In 2015, 196 countries around the world adopted the Paris Agreement with a goal to limit global warming to well below 2 degrees Celsius, and preferably to 1.5 degrees Celsius, compared to pre-industrial levels (UN 2015). Under the Paris Agreement, countries are expected to pledge climate action and submit their plans as National Determined Contributions (NDCs) every five years to the secretariat of the United Nations Framework Convention on Climate Change (UNFCC). As of late 2022, 166 countries have submitted new or updated NDCs, covering an estimated 94.9% of the total global emissions in 2019 (UNFCCC 2022).

The NDCs are based on an approach whereby individual countries pledge their climate actions at the domestic level.[1] These pledges create variations in climate policy across countries, including in terms of policy ambition (e.g., reflected in differences in emission reduction levels or the corresponding carbon prices) and sectoral coverage. A key implication of this is an uneven global playing field, leading to an erosion of the global competitiveness of sectors in countries implementing more stringent climate actions. Another implication, key for climate change, is carbon leakage—namely when climate policies in a country may cause increases in emissions in countries with weaker policies.[2]

Border Carbon Adjustments (BCAs) have been proposed as a mechanism to mitigate the drawbacks from global policy fragmentation. BCAs are intended to complement existing domestic climate policies by allowing countries to pursue and achieve their climate targets while limiting carbon leakage and the erosion of global competitiveness resulting from countries pursuing less stringent climate policies. BCAs may take the form of an import charge and sometimes rebates on exports. In the case of an import charge, BCAs may include a charge on imported goods, typically reflecting the difference in carbon pricing between trading partners and considering the emission intensity of the imported good. In the case of export rebates, domestic sectors exposed to carbon pricing in the home country may receive a financial transfer to preserve their global competitiveness. Likewise, export rebates can be calculated based on the regional differences in carbon pricing and reflecting the emissions intensities of the exported goods.

There is increasing momentum around the use of BCAs as countries move forward with the implementation of their domestic climate policy frameworks. For example, the Government of Canada initiated public consultations exploring the use of BCAs for a variety of fossil fuel and emissions-intensive trade-exposed (EITE) sectors, which account for more than 70% of Canada's exports.[3] Similarly, the European Union (EU) has recently started to implement BCAs across a subset of EITE sectors.[4]

Against this backstop, this paper examines the role played by BCAs in addressing the unintended consequences associated with uncoordinated global climate action. The analysis focuses on Canada-specific implications on carbon leakage, domestic and foreign competitiveness (measured as changes in market shares), and welfare (measured as changes in equivalent variation[5]). We investigate these implications under different BCA design features and in consideration of the countries adopting BCAs. To help frame country participation, and consistent with related papers in the literature, we take a coalition versus non-coalition approach.[6] The coalition represents a group of countries pursuing and achieving their climate actions as set out under their respective NDCs. In this paper the coalition comprises Canada, the United States, the EU, Japan, Korea, and Mexico. The non-coalition represents a group of countries assumed to not achieve their NDCs, though they follow their policies and measures in place in 2022 (i.e., their baseline path). This framework also enables us to analyze the implications for Canada when its major trading partner, the US, is not in the coalition. The role of BCAs on the Canadian economy is indeed heavily dependent on whether BCAs are applied in the US, and the degree with which the US pursues climate action.[7]

This paper offers the following contributions to the literature. First, it provides a quantification of Canadian economic impacts resulting from BCAs. Focusing on a country like Canada helps shed light on the role played by the carbon content of a country's traded goods, the role these play in domestic production supply chains, and who the country trades with. Second, the paper considers different BCA design features and the interaction of BCAs with other policies that may also play a role in addressing

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[1] For instance, Canada's latest NDC pledge is to cut its emissions by 40% to 45% below 2005 levels by 2030, with an additional commitment to achieve net-zero emissions by 2050.

[2] See Paltsev, 2001, and Babiker, 2005.

[3] These sectors include oil and gas, mining, food and beverage, wood, pulp and paper, chemicals, petroleum and coal products, motor vehicles and parts, primary and fabricated metals, plastic and rubber products, aerospace products and parts, non-metallic mineral products, and transportation of natural gas (Government of Canada 2021).

[4] Council of the European Union, 2022.

[5] Economic welfare impacts are reported as Hicksian equivalent variation in income, which denotes the amount necessary to add to (or subtract from) the benchmark income of the representative consumer so that she enjoys a utility level equal to the one in the counterfactual policy scenario on the basis of ex-ante relative prices.

[6] See Bellora and Fontagne, 2022.

[7] About 56% of Canada's imports in EITE sectors in 2020 come from the US (based on the authors calculations from the MIT-EPPA model, described in the following section).

carbon leakage and competitiveness matters. Specifically, our analysis accounts for the impact of existing regimes in Canada and the EU that are offering allowances (compliance credits at no charge) to firms to assist them in meeting their greenhouse gas (GHG) emissions limits.

We find that when Canada is part of a broad coalition of BCA-implementing countries, including the US, BCAs, in the form of import tariffs, reduce Canada's carbon leakage and improve its domestic and foreign competitiveness. In addition, when the import tariff revenues are transferred to households, BCAs are welfare improving. We show that these results may differ when the BCA scheme considers differences in sectoral coverage, the addition of export rebates, and Canada's existing regime of free allowances to firms through the output-based pricing system. When the US is not part of the coalition, we show that Canada's carbon leakage increases. While domestic competitiveness is dampened, we show improvements in foreign competitiveness. Independent of whether the US participates in the coalition, the analysis finds that BCAs (only in the form of import tariffs, not export rebates) are welfare improving for Canada in comparison to the case where there are no BCAs.

While important, several challenges were not considered in the present analysis. With regard to compliance with the World Trade Organization (WTO), trade between countries will be exposed to different levels of adjustments, creating concerns BCAs could be in violation of the non-discrimination clause. However, some have argued that since a common mechanism would be used in determining these adjustments, varying BCAs by trading partner might not, on its own, violate this principal (Bellora & Fontagne 2022). Yet other aspects of BCA design create WTO compliance concerns, including discrimination based on foreign countries' emissions intensities, ensuring BCAs reflect the full spectrum of climate change mitigation policies beyond just carbon prices, the redistribution of revenues generated by BCAs, and concerns over the potential rebates to industry.

Beyond the WTO, there are additional challenges to the implementation of BCAs. For one, the introduction of BCAs could trigger retaliation by relevant trading partners, confounding the economic impacts. In Canada, questions remain whether BCAs would be compliant with existing free trade agreements, including the United States-Mexico-Canada Agreement (USMCA).[8] In addition, Canadian provinces have led the development of carbon pricing schemes, and imposing additional tariffs as a BCA measure at the federal level would be another challenge (Cosbey *et al.* 2021).[9] Conscious of the many limitations of implementing BCAs, this paper focuses on a set of illustrative scenarios intended to shed light on their potential economic impacts in Canada.

The paper is organized as follows. Section 2 reviews the research related to BCAs. Section 3 outlines the modelling framework used in this study. This section also provides a detailed description of how embodied emissions, BCAs, carbon leakage, and competitiveness are calculated, as well as an overview of the scenarios considered for the analysis. Section 4 presents the results of our analysis, considering various BCA design features (sectoral coverage, export rebates, interaction of BCAs with free allowances) as well as the implications for when the US is out of the coalition. Concluding remarks follow.

2. Relevant research

The literature examining BCAs has focused on carbon leakage, international competitiveness, and economic efficiency and welfare.[10] In terms of carbon leakage, the literature argues for two main channels. The first is the competitiveness channel, where carbon-intensive sectors reduce their domestic production because of higher operating costs associated with domestic climate policies, while production by sectors in countries facing less stringent climate policies increases, thereby increasing their emissions. The second is the fossil fuel price channel, where the decreased demand for fossil fuels driven by abating countries puts downward pressure on the price of fossil fuels in world markets, which further increases their use and emissions in countries with less stringent climate policies. The consensus in the liter-

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[8] Lilly *et al.*, 2022 shows that while a carefully designed Canadian BCA could be both WTO-legal and permissible under Canada's major trade agreements, serious political and economic challenges are likely to arise.

[9] In addition, our study is silent on some of the macroeconomic implications of imposing BCAs, such as changes in exchange rates. This is examined in McKibbin *et al.*, 2018.

[10] Our results are generally aligned with what is found in the literature at the global level. First, BCAs can improve global cost-effectiveness by partially transferring carbon pricing via trade flows to trading partners without emissions pricing policies. However, the magnitude of the efficiency gains may be limited due to the small fraction of emissions abroad (those that are imported in covered goods) that can be targeted, and foreign EITE industries may also reroute part of their exports to other non-regulated markets (Bohringer *et al.* 2012). Furthermore, the impact of BCAs on economic welfare has been investigated, with Winchester (2017) arguing that US welfare is lower when it met its Paris pledge as compared to when it faced BCAs but did not regulate GHG emissions—concluding that BCAs will not be effective in enforcing climate commitments in the US. Import adjustments on embodied carbon applied by richer, industrialized countries may also shift some of the burden of emissions pricing to poorer, developing countries. Such equity concerns can be addressed by returning the revenue from carbon import adjustments to paying countries or using it for technology transfer and international climate finance (Bohringer *et al.* 2022).

ature is that BCAs are moderately successful at reducing carbon leakage (Winchester *et al.* 2011).[11]

Studies that have looked at the competitiveness dimensions of BCAs generally find that BCAs modestly impact production losses or market share of domestic EITE sectors in favour of countries with weaker climate policies (Bohringer *et al.* 2012, Fouré *et al.* 2016). Several analyses using computable general equilibrium models have shown that significant output losses occur in energy-intensive sectors when a domestic climate policy is enacted (e.g., cap-and-trade or carbon price), and that BCAs are insufficient to counteract the impacts of the other policies (Burniaux *et al.* 2010; Mattoo *et al.* 2009, Winchester *et al.* 2011). Burniaux *et al.* (2010) attributes this to the fact that energy-intensive industries are affected primarily by the contraction of the overall market size that comes from carbon pricing, rather than by losses accruing to the international competitiveness channels. Similarly, Aldy and Pizer (2015) argue that most domestic production loss stems from energy price increases and reduced overall consumption rather than the loss of competitiveness in its product markets. Monjon and Quirion (2011) analyzed European climate policy and found that a decrease in EU production of energy-intensive products can be expected, but mainly due to a reduction in European demand rather than a shrinking global market share.

The efficacy of the EU's BCA scheme has been analyzed in Bellora and Fontagne (2022). Using a dynamic general equilibrium model, the authors simulate various BCA schemes consistent with the EU's proposed plan that covers non-fossil-fuel emissions-intensive sectors. The authors find the proposed plan is effective in reducing carbon leakage, but only partially effective in mitigating competitiveness losses. The authors argue that BCAs push up the domestic price of carbon, leading to increased prices for intermediate products used in downstream sectors. The authors further investigate the impacts of the design of BCAs as they relate to WTO rules and find that, while BCAs are most effective when constructed to discriminate against export markets, they indeed run the risk of violating WTO rules.

3. Modelling framework

3.1 General equilibrium model

We employ the MIT Economic Projection and Policy Analysis model (the MIT-EPPA model), which is a recursive-dynamic general equilibrium model representing the world's economy across several countries/regions and sectors relevant for the consideration of climate policy design and BCAs (Chen *et al.* 2022a). An important characteristic of the MIT-EPPA model is the representation of links among sectors through each firm's use of domestic and imported intermediate inputs. Purchases of intermediate inputs are captured in input-output tables calibrated in the base year to aggregated data from the Global Trade Analysis Projection dataset (Aguiar *et al.* 2019). For each sector, these tables list the value of output produced and the value of each input used, which can be linked to physical quantities (e.g., tonnes of coal).[12] Further details on the MIT-EPPA model can be found in Appendix A, including the regional and sectoral representations used in this paper.

For the assessment of BCA impacts, we enhance the MIT-EPPA model in several dimensions. First, we disaggregate the energy-intensive sector in the MIT-EPPA7 model into three subsectors (i.e., iron and steel, cement, and other energy-intensive industries). Second, we use dynamic emission intensities in calculating embodied emissions. Third, the model now treats oil as a heterogenous globally traded commodity. Finally, we introduce a representation of BCAs in the form of import charges and export rebates.[13] The following subsections expand further upon some of the key assumptions and calculations in our analysis of BCAs, with additional information on the MIT-EPPA model provided in Appendix A.

3.2 Embodied emissions

Embodied emissions, which are important for the analysis of BCAs, refer to the total life cycle emissions associated with the production of a good. One can think of this as representing both the emissions directly associated with the production of end products plus any emissions passed through the supply chain. The ability for the MIT-EPPA model to capture links across sectors enables a detailed tracking of both direct and indirect emissions embodied within end products. Embodied emissions are therefore a function of the direct emissions and indirect emissions of producing a good, given as:

$$e_i^r = d_i^r + \sum_j e_j^r \cdot \alpha_{ij}^r \cdot \delta_j^r$$

where e_i^r is the embodied emissions in good *i* produced in region *r*. The first term on the right-hand side is the direct

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[11] The 29th study by the Energy Modeling Forum (EMF), which considers a 20% emissions reduction in the industrialized world (countries listed in Annex 1 of the Kyoto Agreement), found that the BCAs for EITE industries reduce leakage rates by about one-third (Bohringer *et al.* 2012). In the reference scenario in Bohringer *et al.* (2012), leakage rates range between 5% and 19% with a mean value across all models of 12%. BCA is effective in reducing leakage. Leakage rates under BCA range between 2% and 12% with a mean value of 8%. Thus, the carbon-based import tariffs and export rebates to EITE products reduce the leakage rate on average by a third compared to the reference scenario with uniform emission pricing only. Analysing 25 studies, Branger and Quirion (2014) show that in the majority of the cases, the leakage ratio reduction due to BCAs stands between 1 and 15 percentage points. Their meta-regression analysis shows that all parameters being constant in the meta-regression analysis, the ratio drops by 6 percentage points with the implementation of BCAs.

[12] For example, the coal power sector will use inputs of capital and labour and outputs from the coal mining sector along with other intermediate inputs to produce electricity.

[13] More details of these changes will be presented in subsections 3.2-3.3.

emissions of production of good *i* in region *r*, given as d_i^r. The second term on the right-hand side is the indirect emissions embodied in input *j* used to produce good *i*, where α_{ij}^r refers to the input *j* per unit of good *i*, and δ_j^r is the share of *j* sourced domestically. Re-arranging this equation allows one to solve a system of *n* equations with *n* unknowns e_i^r:

$$e_i^r \cdot (1 - \alpha_{ii}^r \cdot \delta_i^r) - \sum_{j \neq i} e_j^r \cdot \alpha_{ij}^r \cdot \delta_j^r = d_i^r$$

3.3 Border carbon adjustments

BCAs primarily take the form of import tariffs, and sometimes rebates on exports. In the case of import tariffs, BCAs may include a charge on imported goods based on their emissions intensity or embodied emissions. The import tariff is represented as an ad valorem tariff, calculated as follows:

$$\tau_i^d = \frac{\left(CP^d - CP^o\right) \times e_i^o}{p_i^o}$$

where CP^d and CP^o are the carbon prices in the importing and exporting region, respectively, e_i^o is the tonnes of carbon dioxide (CO_2) emissions embodied in each unit of good *i* in the exporting country, and p_i^o is the unit price of good *i* exported from region *o* to region *d*. Carbon prices in the model are represented by shadow prices. These prices are calculated endogenously in the model and represent what could be a broad range of climate policy actions needed to meet the emission reduction targets specified for each region/country.

In the case of export rebates, domestic sectors exposed to carbon pricing in the home country may receive a financial transfer to preserve their global competitiveness. When export rebates are considered in this paper, the export rebate is calculated as follows:

$$R_i^o = \frac{\left(CP^o - CP^d\right) \times e_i^o}{p_i^o}$$

Some of the import tariff rates and export rebates calculated based on these definitions are presented in Figure 9 and Figure 10 in Appendix B.

3.4 Carbon leakage and competitiveness definitions

Carbon leakage is defined as the amount of domestic emission reductions that gets offset by the increases in emissions abroad. To measure carbon leakage, one can compare emissions changes in the non-coalition countries with those in the coalition countries as follows:

$$Carbon\ leakage\ rate = \frac{Emissions_{NCOA}^{policy} - Emissions_{NCOA}^{baseline}}{\left|Emissions_{COA}^{policy} - Emissions_{COA}^{baseline}\right|} \times 100$$

where COA refers to coalition countries, NCOA refers to non-coalition countries, baseline refers to the baseline scenario, and policy refers to scenarios where at least some countries pursue more ambitious climate policy as compared to the baseline (NDCs for COA and baseline for NCOA). The denominator is represented as an absolute number to represent leakage based on how much non-coalition countries emissions change given the reduction in emissions in coalition countries. For example, an 8% leakage ratio implies that 8% of the emissions reduction achieved in coalition countries is offset through increased emissions in non-coalition countries.

In this study, foreign competitiveness is defined as the change in a country's export market share in total global exports. Domestic competitiveness in turn is measured for each sector *i* and is calculated as follows:

$$Domestic\ market\ share_i = \frac{Production_i - Exports_i}{Domestic\ supply_i}$$

where we have:

$$Domestic\ supply_i = Production_i - Exports_i + Imports_i$$

3.5 Free allowances

Other climate policy measures, including in the EU and Canada, are also aimed at addressing the potential for carbon leakage and competitiveness loss associated with the relative stringency of their climate policies. The scenarios constructed as part of this analysis were developed considering the role of such policies, namely, the role of free allowances.

To safeguard the competitiveness of industries covered by the EU's Emissions Trading System (ETS), industrial facilities deemed to be exposed to significant risk of carbon leakage receive a higher share of free allowances compared to other industrial facilities. One of the main components of the EU's Carbon Border Adjustment Mechanism (CBAM) is the progressive phasing out of free allowances under the ETS over a ten-year period.[14] As of 2026, when the CBAM will come into effect, free allocations to European emitters will be gradually reduced by 10% per year, with the system fully replacing the free allowances by 2036. As stated by the European Commission, the CBAM is an alternative to free allocation, and as such the two measures should not overlap.[15]

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[14] The CBAM was applied from 1 January 2023 with a transitional period until the end of 2026, and European Parliament believes it must be fully implemented for the above-listed sectors of the EU ETS by 2032. Sectors that are included under EU's ETS phase 3 (2013–20) are power stations, oil refineries, coke ovens, iron and steel plants, cement clinker, glass, lime, bricks, ceramics, pulp, paper and board, aluminium, petrochemicals, ammonia nitric, adipic and glyoxylic acid production, CO_2 capture, transport in pipelines and geological storage of CO_2, and aviation. For more details see EU ETS Handbook. The corresponding sectors in the EPPA model that receive the free allowances are iron and steel, cement, other energy-intensive industries, and electricity. Sectors that are included under CBAM are iron and steel, cement, fertilizer, aluminium, electricity generation, organic chemicals, plastics, hydrogen, and ammonia. For more details see European Commissions documentation on CBAM.

[15] https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3542

In Canada's federal output-based pricing system (OBPS), registered industrial facilities are exempt from the carbon pricing scheme for fuel purchases but are required to pay for the portion of their emissions that exceed their annual facility GHG emissions limit.[16] Specifically, the OBPS establishes emission intensity performance standards for regulated industries, and using those standards, GHG emission limits are calculated for facilities based on their annual economic production. Facilities are issued compliance credits up to their annual GHG emissions limits at no charge. Facilities that exceed their annual limit may purchase additional compliance credits from facilities with surplus credits, acquire verified offset credits from elsewhere (e.g., verified GHG mitigation projects in other jurisdictions or non-regulated sectors), or purchase compliance credits from the government. Over time, stringency levels can be increased by adjusting emission intensity performance standards to allow for fewer GHG emissions per unit of production and by increasing the price of compliance credits.[17]

3.6 Scenarios

To examine the effects of BCAs on the Canadian economy, we take a coalition versus non-coalition approach, where coalition countries represent a group of countries that are assumed to pursue and achieve their climate ambitions as set out under their respective NDCs. The non-coalition countries are assumed to follow current policies in place in 2019 as outlined under stated and current policies and targets.[18] The time horizon chosen for this study is until 2030. We select this time horizon given our interest in examining the contemporaneous impacts of BCAs on key indicators. Also, the NDCs generally cover this period.

To determine coalition countries, we follow Bellora and Fontagne's (2022) approach in assuming that countries with existing and mature domestic carbon pricing schemes are credible in their efforts to achieve their climate objectives as outlined in their NDCs. Based on the Carbon Pricing Dashboard developed by the World Bank, 18 countries and regions had national carbon pricing systems in 2021: Argentina, Canada, Chile, Colombia, the EU, Iceland, Japan, Kazakhstan, Korea, Mexico, Montenegro, New Zealand, Norway, Singapore, South Africa, Switzerland, United Kingdom, and Ukraine. Of these countries, Canada, the EU, Japan, Korea, and Mexico are distinct regions in the MIT-EPPA model (see Figure 8 in Appendix A). As such, these countries and regions are retained in our analysis. Further, to draw attention of the role played by Canada's main trading partner, the US, we first assume that the US is in the coalition. This assumption will be relaxed, enabling the comparison of results when the US is out of the coalition.[19]

We developed three main scenarios, which are outlined in **Table 1**. Under the first scenario, the *baseline scenario*, emission targets are aligned with the current climate policies for all countries/regions, though they are considered insufficient to achieve the emission reduction targets. In the second scenario, the *uncoordinated scenario*, coalition countries/regions pursue and achieve their NDCs,[20] while the non-coalition countries/regions continue along their baseline path. Contrasting the uncoordinated and baseline scenarios allows us to shed light on the consequences of a lack of global climate policy coordination.

We also consider another version of the *uncoordinated scenario* that examines the implications of free allowances, introduced in section 3.5. Building on the *uncoordinated scenario*, the *uncoordinated with allowances scenario* (Scenario 2a in Table 1) assumes that specific sectors in Canada and the EU receive free allowances according to a constant portion of what they pay under the respective carbon pricing schemes. To determine what fraction of facilities receive these free allowances, we examined data from the EU's ETS and Canada's OBPS. In the case of the EU, over the period 2013–20, 57% of the allowances on the ETS were auctioned, while the remaining 43% were freely allocated to sectors deemed to be exposed to a risk of carbon leakage.[21] Based on this information, when considering scenarios that include allowances, we assume in the MIT EPPA model that the EU's sectors that are regulated under the ETS receive allowances equivalent to 43% of their

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[16] Under the OBPS that is designed for industrial emitters with GHG emissions of 50,000 tonnes CO_2e or greater, a facility's annual emission limit would be calculated by multiplying the facility's total annual production by the applicable emission intensity performance standards for its activities. Each facility would pay for any GHG emissions that exceed its limit at a rate of $10 per tonne of CO_2e in 2018, rising by $10 per year, up to $50 per tonne of CO_2e in 2022. Sectors covered under the OBPS include oil and gas production, mineral processing, chemicals, pharmaceuticals, iron and steel, mining and ore processing, lime and nitrogen fertilizers, food processing, pulp and paper, automotive, electricity generation, and cement. For each of these sectors a benchmark emission intensity is specified in the policy, which can be found in Canada's Output-Based Pricing System Regulations (see Government of Canada 2019). These sectors correspond to the following sectors in the EPPA: oil and gas, cement, iron and steel, other energy-intensive industries, other manufacturing industries, food, and electricity.

[17] While such allowance systems allow domestic carbon-pricing schemes to both change relative prices and incentivize decarbonization, they alleviate the economic pressures on carbon-intensive industries, mitigating the consequences of the domestic policy design.

[18] Renewable shares are one of these targets, which are plotted in Figure 11 in Appendix C for some of the regions.

[19] For results related to the consequences of unilateral policy design and the number of countries implementing emissions reduction commitments, see Reinaud 2008, Bohringer *et al.* 2012.

[20] The emission targets of the coalition countries/regions under NDC are outlined in Table 6 in Appendix C.

[21] See Bellora and Fontagne 2022.

Table 1 Scenario description

Scenarios	Coalition	Non-coalition	BCA design	BCA imposed	Free allowances	Sectoral coverage
1) Baseline	Baseline	Baseline	-	-	No	-
2) Uncoordinated	NDC	Baseline	-	-	No	-
2a) Uncoordinated with allowances	NDC	Baseline	-	-	Yes	-
3) Allowances + BCA (partial coverage | tariffs only)	NDC	Baseline	Imp tariff	Coalition	Yes	Partial

Coalition = Canada, US, EU, Japan, Korea, and Mexico

Non-coalition = all other countries

NDCs = nationally determined contributions

Baseline = current policies

Full = sectoral coverage refers to cement, coal, food, gas, iron and steel, oil, other energy-intensive sectors, other manufacturing sectors, and refined oil

Partial = sectoral coverage excludes fossil fuels and only includes cement, iron and steel, other energy-intensive sectors, and other manufacturing sectors

carbon price costs.[22] For Canada, based on facility-level 2019 emissions data, 32% of Canadian emissions were on average from facilities emitting GHG emissions of 50,000 tonnes CO_2e or greater per year and fell under the OBPS.[23] We assume these Canadian facilities receive allowances equivalent to 32% of their carbon price costs.[24]

Under the third scenario, coalition countries/regions impose BCAs on imports from the non-coalition countries/regions. We call this third scenario the *Allowances + BCA (partial | tariffs only)* scenario. In this scenario, BCAs take the form of import tariffs (no export rebates) and are imposed on a partial set of emissions-intensive sectors (i.e., cement, iron and steel, other energy-intensive sectors, and other manufacturing sectors). We first study the case where BCAs are imposed on only this partial set of EITE sectors. The *Allowances + BCA (partial | tariffs only) scenario* also assumes the inclusion of allowances. Finally, under all scenarios, revenues raised from imposing BCAs (from the import tariffs) are redistributed back to households via lump-sum transfers.[25] Given our interest in examining whether the design of the BCA scheme matters, we later explore the effects of expanding sectoral coverage, adding export rebates on top of import tariffs, and the interplay of allowances and BCAs.

4. Results

4.1 Impacts on carbon leakage, competitiveness, and welfare

Table 2 shows the cumulative impacts on carbon leakage, domestic and foreign competitiveness, and welfare (measured as changes in equivalent variation) of the different scenarios over the 2020–30 period and relative to the baseline. Under the *uncoordinated scenario*, around 6.1% of Canada's emission reductions are offset by increases in emissions outside of Canada.[26] In addition, Canadian

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[22] For the EU, these sectors are iron and steel, cement, other energy-intensive industries, and electricity generation. For Canada, these sectors correspond to oil and gas, cement, iron and steel, other energy-intensive sectors, other manufacturing sectors, food, and electricity.

[23] To calculate this number we leveraged the facility-reported greenhouse gas data and provinces' total GHG emissions from National GHG inventory reports. Considering jurisdictions that either have their own OBPS, a cap-and-trade system, or fall under the federal OBPS system, in 2019, on average, 32% of Canada's total GHG falls under this system.

[24] This assumes that the OBPS emission intensity benchmark for each sector is the same as the average emission intensity of the sector in the model. In addition, total payment of the firms that have emission intensity higher than the sector's benchmark is equal to what the firms who are below the benchmark receive in that sector, resulting in no payment by sector in total. Since the MIT-EPPA model is at the sector level, we cannot model the heterogeneity within sectors in this paper to study the effects of the OBPS with more accuracy. Therefore, we assume that a representative firm of a sector included in the OBPS and the EU's ETS receives a fraction of what it pays under carbon pricing, and that fraction is the same as the share of emissions that fall under the OBPS. This means sector i, which is included in the OBPS and the EU's ETS, receives $R_i = \beta \times CP \times e_i$, where β is the fraction of emissions that fall under these policies, CP is national carbon price, and is the emission level of the sector (which is a function of its production level).

[25] BCA revenues can also be used to reduce distortionary taxes (McKibbin *et al.* 2018). Allocation of BCA revenues to the exporting countries is another option that can avoid shifting the burden of BCAs to developing countries (Bohringer *et al.* 2012; Fischer and Fox 2012). In fact, returning the BCA revenue to the paying countries or using it for technology transfer and international climate finance would likely improve a BCA regime's chance of success in meeting GATT's exception requirements by helping to demonstrate the BCA's environmental objectives (Cosbey *et al.* 2019, Bohringer *et al.* 2022). In this study, given the model limitations in terms of labour or capital distortionary taxes and to avoid implications of international transfers, we assume revenues raised from the import tariffs are redistributed back to households via lump-sum transfers.

[26] In this study, since countries/regions are constrained to reach their emission targets in 2030, emission variations are expected to be lower than those studies that do not impose constraints on emissions. For example, see Ecofiscal Commission (2016), which calculates Canada's leakage rate to be around 20%.

Table 2 Cumulative impacts over the 2020–30 period relative to baseline

Scenarios	Carbon leakage rate	Domestic market share	Foreign market share	Welfare
Units	*percentage*	*percentage point change*	*percentage point change*	*percentage changes in equivalent variation*
2) Uncoordinated	6.10	-0.43	-0.05	-0.67
2a) Uncoordinated with allowances	4.38	0.12	-0.03	-0.78
3) Allowances + BCA (partial | tariffs only)	-1.07	0.52	0.04	-0.71

producers lose 0.43 percentage points of their domestic market share and 0.05 percentage points of their foreign market share due to the stricter climate policies that they face. This scenario also shows that welfare declines by 0.67 percentage points.

When introducing free allowances, Canada's carbon leakage is reduced from 6.1% to 4.38%. Free allowances also bring down the costs of production, improving competitiveness both domestically (0.55 percentage point change) and internationally, albeit at a lower level (only 0.02 percentage point change). Despite the introduction of allowances, welfare declines further due to deadweight losses associated with this form of support.[27]

When BCAs are introduced on top of allowances, we find that BCAs are effective in reducing carbon leakage from Canada to the rest of the world. Cumulative carbon leakage between 2020–30 might even become negative when BCAs are imposed, showing that non-coalition countries/regions might emit below their baseline under this scenario. Negative leakage is more likely when the elasticity of substitution between the good produced in the coalition countries/regions and the good produced in the non-coalition countries/regions is lower (as this reduces the terms-of-trade effect).[28] In terms of welfare changes, imposing BCAs on top of free allowances mitigates some of the welfare loss relative to the *uncoordinated scenario* (from -0.78 to -0.71 percentage change). Here, revenues from imposing BCAs, which are only in the form of import tariffs and returned to households, provide some compensation for losses due to higher prices (discussed below) resulting from the implementation of BCAs.

In terms of competitiveness, the results suggest that BCAs are effective in improving the domestic and foreign competitiveness of Canadian producers. **Figure 1** shows the changes in average export market shares in the EITE sectors relative to the baseline under the three scenarios covered in Table 2. Under the *uncoordinated scenario*, coalition countries/regions (i.e., Canada, the EU, the US, Japan, Korea, and Mexico) lose market share due to their implementation of more stringent climate policies. While allowances (introduced only in Canada and the EU) improve the average export market share for Canada, they are not as effective as BCAs in flipping this share in favour of the coalition. When BCAs are introduced on top of allowances, Canada and the rest of the coalition gain export market shares and non-coalition countries/regions lose shares.

Another important implication of BCAs is the creation of a wedge between domestic prices and international prices. In the model, the sectoral price is the price that all producers in the economy pay for purchasing that sector's output and is an Armington composition of domestic and import prices. As shown in **Figure 2**, the introduction of allowances generally put downward pressure on sectoral prices (orange bars). Adding BCAs, however, mitigates some of the downward pressure on sectoral prices (blue bars), but only for those sectors covered by the import tariff (cement, iron and steel, other energy-intensive sectors, and other manufacturing sectors). Since Canada is a net importer in these four sectors, we find an increase in the sectoral prices due to BCAs.

Figure 3 shows the positive financial impacts (defined as the difference between revenues and costs) for the cement, iron and steel, other energy-intensive sectors, and other manufacturing sectors. Producers benefit from higher prices for their output and higher domestic market shares because of the implementation of BCAs in the form of an import tariff.

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[27] This result is akin to the deadweight loss typically associated with production subsidies, namely the higher costs to government relative to the additional benefits accruing to consumers and producers.

[28] Negative leakage can also occur when the elasticity of substitution between clean inputs and fossil fuels is higher, as this increases the abatement resource effect. The abatement resource effect happens when increased demand for capital and labour to replace fossil fuels in carbon-taxed regions attracts factors of production from unregulated regions, which decreases unregulated output and ultimately emissions. For more explanation on negative leakage rates see Winchester and Rausch (2013). Given that in the EPPA model used in this study there is no capital and labour movement across countries, negative leakage ratios cannot be attributed to the abatement resource effect. Overall, negative leakage means non-coalition countries/regions might emit below their baseline after coalition countries/regions impose BCAs.

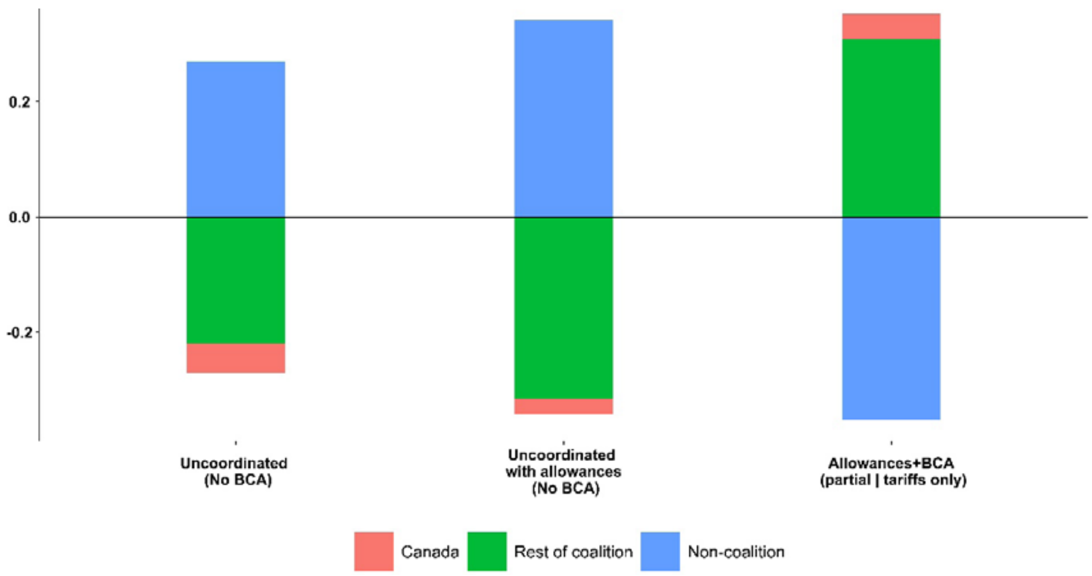

Figure 1 Average export market share changes in EITE sectors (2020–30) relative to the baseline scenario (percentage point change)

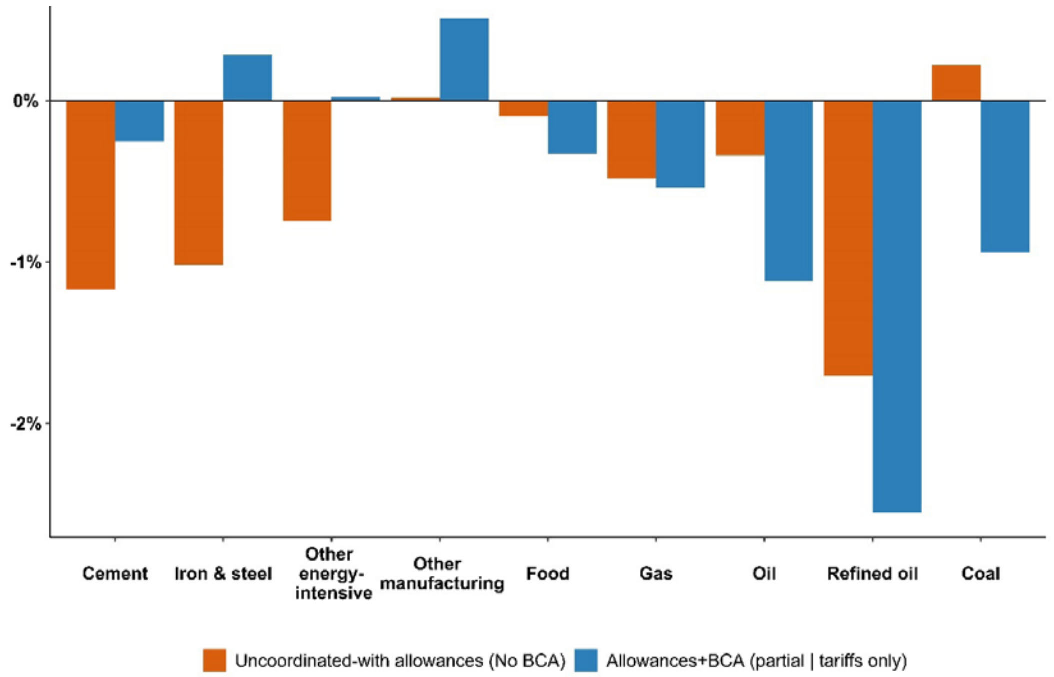

Figure 2 Average sectoral price changes (2020–30) relative to the uncoordinated scenario (%)

4.2 Does the design of BCAs matter?

To examine the design implications of BCAs, we consider the following features: 1) expanding the sectoral coverage to include fossil fuels and food sectors;[29] 2) adding export rebates (as defined in section 3.3) on top of import tariffs, with part of the revenues from the import tariffs now returned to EITE sectors; and 3) replacing allowances with BCAs starting in 2020.[30] **Table 3** summarizes the results associated with these additional design features. For ease of comparison, Table 3 also presents the previous relevant results, namely those related to the scenario considering the

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[29] The food sector is an energy-intensive trade-exposed sector according to the Government of Canada (2021).

[30] As explained in section 3.3, the phasing out of free allowances is a scenario that is closer to what is proposed under initiatives like the CBAM. In fact, keeping free allowances while imposing import tariffs can be interpreted as double protection for domestic industries, raising challenges with WTO rules. It is for this reason that we consider the phasing out of the allowances.

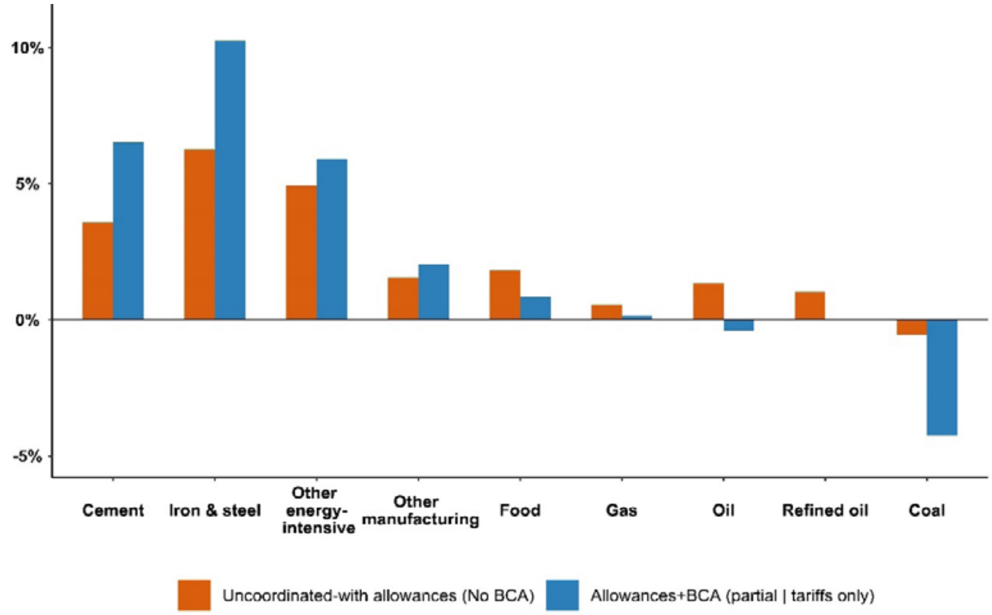

Figure 3 Cumulative (2020–30) sectoral financial impacts relative to the uncoordinated scenario (%)

Table 3 Cumulative (2020–30) impacts of different BCA design features relative to baseline

BCA design features	**Carbon leakage rate**	**Domestic market share**	**Foreign market share**	**Welfare**
Units	*percentage*	*percentage point change*	*percentage point change*	*percentage changes in equivalent variation*
Allowances and import tariffs				
Allowances + BCA (partial I tariffs only)	-1.07	0.52	0.04	-0.71
1. Expanding the sectoral coverage				
Allowances + BCA (full I tariffs only)	-1.16	1.01	0.04	-0.71
2. Combining import tariffs and export rebates				
Allowances + BCA (partial I tariffs & rebates)	-1.85	0.55	0.08	-0.78
3. Replacing allowances with BCAs				
BCA (partial I tariffs only)	0.75	0.01	0.02	-0.59

Full = sectoral coverage refers to cement, coal, food, gas, iron and steel, oil, other energy-intensive sectors, other manufacturing, and refined oil

Partial = sectoral coverage excludes fossil fuels and only includes cement, iron and steel, other energy-intensive sectors, and other manufacturing

joint implementation of allowances and BCAs, and when the later are in the form of import tariffs and applied to a partial set of sectors.[31]

First, expanding the sectoral coverage does not significantly change the effects of BCAs on carbon leakage (from -1.07 to -1.16 percentage point change). Part of the reason for this is because import tariffs are most relevant for sectors for which imports play a key role in the domestic economy—which in the Canadian context are those partial sectors (cement, iron and steel, other energy-intensive, and other manufacturing). In the case of fossil fuels, for example, Canada is a net exporter, and BCA import tariffs do little to affect carbon leakage from those sectors. However, expanding the sectoral coverage does increase the basket of imports exposed to tariffs, leading to an increase in the domestic market share relative to partial coverage (from 0.52 to 1.01 percentage point change). The foreign market share in turn remains unchanged at 0.4% change, as BCA import tariffs do not explicitly target exports. This case does not affect aggregate welfare.

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[31] We focused on scenarios shown in Table 3 to explain the effects of changing only one aspect of the policy design each time. Results from other scenarios studied are presented in Table 7 in Appendix D.

Second, when export rebates are combined with import tariffs, carbon leakage is further reduced (-1.85 compared with –1.07) as less domestic production is lost in foreign markets to foreign competitors with weaker domestic climate policies. The results for this case show that the improvement in the domestic market share remains relatively unchanged (from 0.52 to 0.55 percentage point change), though the foreign market share increases (from 0.04 to 0.08 percentage point change). The addition of export rebates further levels out climate policy costs embedded in the price of goods between trading partners, alleviating losses in competitiveness in foreign markets. Yet the costs of this redistribution, as well as the general upward pressure on prices that export rebates induce (also discussed below in **Figure 4**), leads to a slight reduction of welfare (from -0.71 to -0.78 percentage point change).

Finally, replacing allowances with BCAs is less effective in mitigating carbon leakage than when they are combined (0.75 compared with -1.07 percentage point change). This case also reduces domestic market share (0.01 compared with 0.52 percentage point change) and foreign market share (0.02 compared with 0.04 percentage point change) for relevant Canadian sectors. However, aggregate welfare loss is smaller when allowances are replaced with BCAs (-0.59 compared with -0.71 percentage point change). As discussed previously, the size of welfare loss due to allowances is larger than the welfare gains from BCAs.

In terms of impacts on sectoral prices, Figure 4 shows that while expanding sectoral coverage does not have significant impacts on sectoral prices, combining import tariffs with export rebates slightly increases these prices. In addition, replacing allowances with BCAs generally results in higher sectoral prices in comparison to the case when BCAs are combined with allowances. This is due to the downward pressure of allowances on sectoral prices. Also, under all design features considered, we observe price increases (or if they drop, the decrease is smaller than for other sectors) for those sectors in which imports have a higher share in domestic supply (cement, iron and steel, other energy-intensive sectors, other manufacturing sectors, and food).

Figure 5 shows the sectoral financial impacts for the different BCA design features studied. First, while expanding sectoral coverage does not have significant financial impacts, combining import tariffs with export rebates provide benefits for some sectors, such as the energy-intensive sector. Second, combining BCAs with allowances provides more benefits for some producers relative to replacing allowances with BCAs. There are multiple channels through which BCAs affect producers. On the one hand, as shown above in Figure 4, sectors with higher rates of imports benefit from the upward pressure of import tariffs on sectoral prices in addition to increasing their domestic market shares. Producers also benefit from the addition of export rebates. On the other hand, producers face higher input costs due to the upward pressure BCAs have on prices, part of which are passed through to consumers. The net effect of these forces depends on the sector. Generally, we see that sectors for which imports have a higher share in domestic supply (cement, iron and steel, other energy-in-

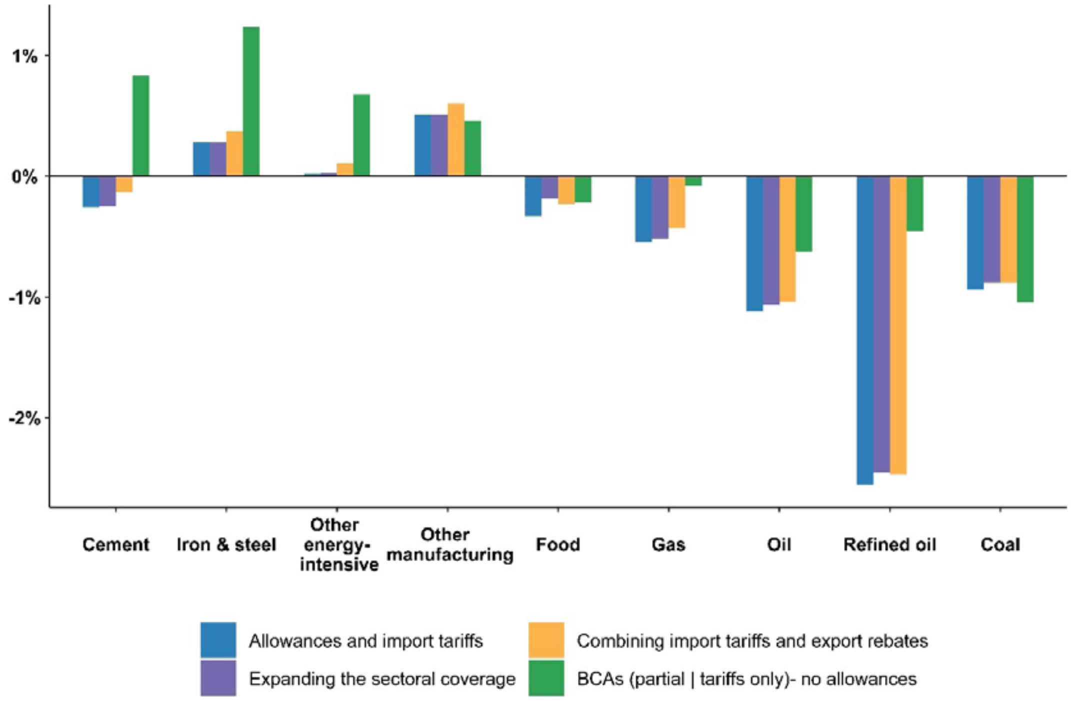

Figure 4 Average sectoral price changes (over 2020–30) relative to the uncoordinated scenario (%)

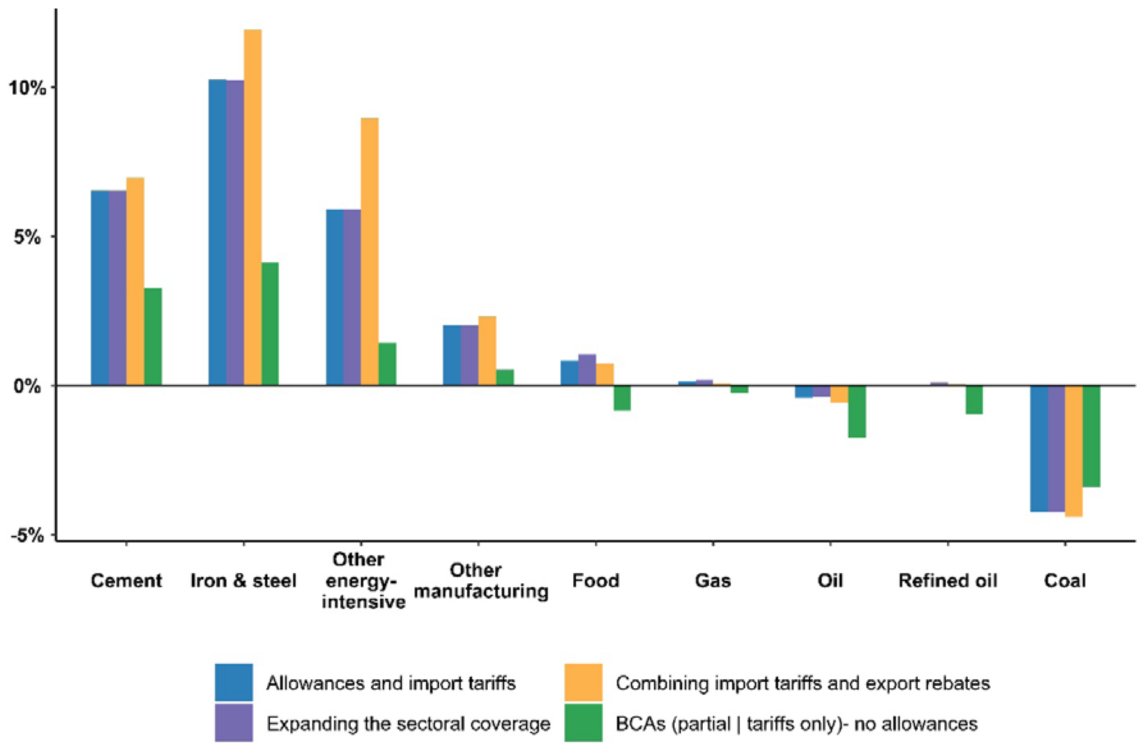

Figure 5 Cumulative (2020–30) sectoral financial impacts relative to the uncoordinated scenario (%)

tensive sectors, other manufacturing sectors, and food) gain more domestic market share under BCAs. In Canada, those sectors are better off, while net-exporting sectors like fossil fuel sectors are slightly worse off.

4.3 What happens when the US is out of the coalition?

Table 4 summarizes results when the US is not in the coalition relative to the case when the US was in of the coalition for the same scenarios covered in Table 2 to capture the broader implications around the adoption of BCAs. In the absence of BCAs, Canada's carbon leakage to the rest of the world increases. In fact, the carbon leakage rate for Canada is higher for all the scenarios studied. In this case, domestic competitiveness deteriorates further since producers in the US now face less stringent climate policies, creating a comparative advantage for them.

When BCAs are introduced, Canada's domestic competitiveness is improved, since in this case Canada imposes tariffs on its main trading partner, the US, as well. However, BCAs result in larger upward pressure on prices in Canada (as shown in **Figure 6**), deteriorating Canada's foreign market share relative to the case when the US was in the coalition.

Furthermore, when the US is out of the coalition, the welfare loss due to the uncoordinated climate policy (no BCAs) is smaller for Canada to begin with (-0.34 relative to -0.67 percentage point change). This shows that more stringent climate policy in the US would have some negative impacts on Canadian welfare. Similar to the case when the US was in the coalition, adding allowances when the US is out decreases welfare (from -0.34 to -0.45), while combining BCAs with allowances increases welfare (from -0.45 to -0.28). However, when the US is out of the coalition, the

Table 4 Cumulative effects (2020–30) relative to baseline—US out of the coalition

Scenarios	Carbon leakage rate	Domestic market share	Foreign market share	Welfare
Units	*percentage*	*percentage point change*	*percentage point change*	*percentage changes in equivalent variation*
2) Uncoordinated	9.10 (6.10)	-0.64 (-0.43)	-0.03 (-0.05)	-0.34 (-0.67)
2a) Uncoordinated with allowances	8.43 (4.38)	-0.09 (0.12)	-0.01 (-0.03)	-0.45 (-0.78)
3) Allowances + BCA (partial I tariffs only)	3.34 (-1.07)	0.66 (0.52)	-0.01 (0.04)	-0.28 (-0.71)

Note: The numbers in parenthesis show the results for the case when the US is in the coalition, previously shown in Table 3.

revenues from imposing tariffs on imports coming from the US is larger, resulting in larger welfare gains when the schemes are combined (from -0.45 to -0.28 instead of going from -0.78 to -0.71 percentage change).

As shown in Figure 6, sectoral prices rise more when BCAs are imposed on US imports in addition to imports from other non-coalition regions to Canada. However, whether the US is in the coalition or not does not have significant financial impacts on Canadian producers (see **Figure 7**). On the one hand, when the US is not part of the coalition, Canadian producers benefit through increased domestic market share when tariffs are imposed on US imports relative to the case where they are not. On the other hand, as shown in Figure 6, sectoral prices rise more when BCAs are imposed on US imports. This in turn increases the input costs for Canadian producers, partly offsetting the gains in the domestic market share.

5. Conclusion and discussion

Differences in the stringency of climate policy across countries have raised questions about their implications for carbon leakage and competitiveness, in particular for industries in

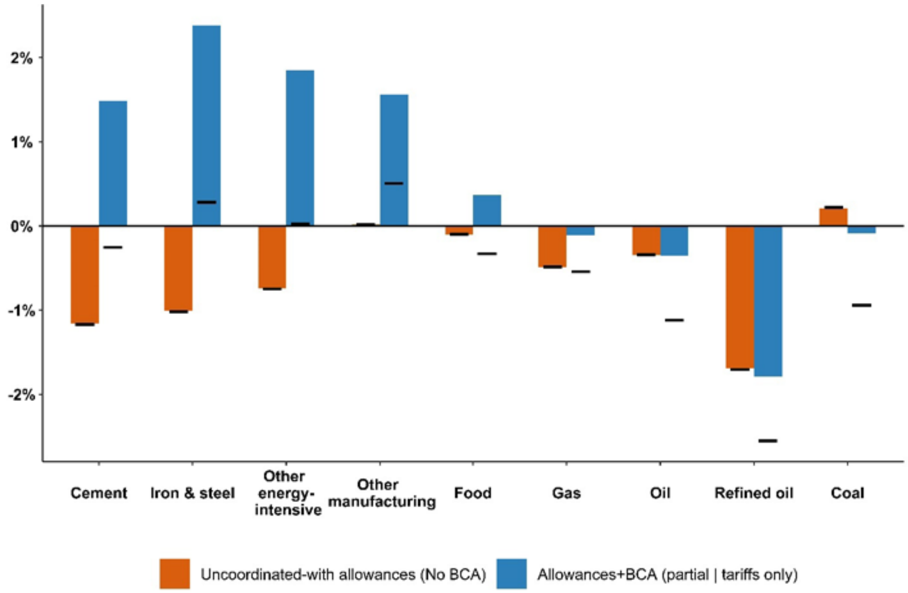

Figure 6 Average sectoral price changes (2020–30) relative to the uncoordinated scenario (%)—US out of the coalition

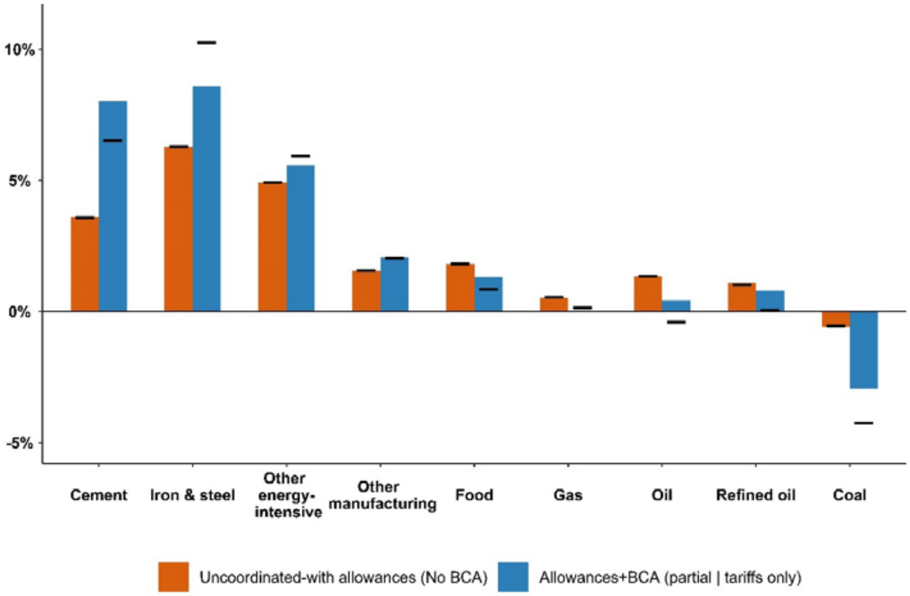

Figure 7 Cumulative (2020–30) sectoral financial impacts relative to the uncoordinated scenario (%)—US out of the coalition

Note: The graph bars show the case when the US is out of the coalition, and the solid black lines represent the case when the US is in the coalition.

countries subject to more stringent climate policies. Measures such as BCAs have been proposed to offset these implications.

This paper provided a quantification of Canadian economic impacts resulting from the implementation of BCAs. We examined implications related to which countries implement BCAs, different BCA design features, and the interaction of BCAs with existing measures also used to address carbon leakage and competitiveness matters. We have shown that the carbon leakage and economic impacts (domestic and foreign competitiveness as well as welfare) resulting from the implementation of BCAs for a country like Canada depend on the role played by the carbon content of a country's traded goods, the role these goods play in domestic production supply chains, and who the country trades with. Our analysis presents both the potential upside and downside of these different considerations, providing valuable insights into understanding the implications to the Canadian economy.

It is important to note that many challenges exist in implementing the various combinations of BCA and allowance schemes represented in this paper, which presents an opportunity for further investigation in the future. For one, since Canadian provinces have led the development of carbon pricing schemes, imposing additional tariffs as a BCA measure at the federal level would be a significant challenge in reality (Boessenkool *et al.* 2022). As a result, one direction for future research is to account for potential differences in BCA measures at the provincial level, provided that regional input-output data for the Canadian economy are available. Another avenue is to explore an additional scenario where retaliations are triggered by trade partners suffering from Canada's BCAs imposed on their exports. To make this feasible, the regional resolution presented in this research may need to be significantly reduced for simplification and computational reasons.

Acknowledgements

We are grateful for comments and suggestions from Madanmohan Gosh, Miguel Molico, Nicholas Rivers, and comments received from participants of the 2022 Canadian Economics Association Annual Meeting and the 2022 Bank of Canada Annual Conference. All remaining errors are our own. The views presented in this paper are those of the authors and do not represent the Bank of Canada's position. The EPPA model employed in the analysis is supported by an international consortium of government, industry and foundation sponsors of the MIT Joint Program on the Science and Policy of Global Change (see the list at: https://globalchange.mit.edu/sponsors/current).

Appendix A: MIT's Economic Projection and Policy Analysis model

The MIT-EPPA model represents interactions among three types of agents in each region of the model: producers, consumers, and the government. In each sector of the model, producers maximize their profits and minimize their costs of production by combining factors of production (capital, labour, land, resources) and intermediate inputs (i.e., goods produced by other sectors) subject to production functions and costs. Consumers are depicted by a representative agent in each region that maximizes households' welfare. Households own the primary factors of production, which they rent to producers (firms). Households then use the income from the rents received to purchase goods and services. The government sets policies and collects tax revenues and then spends the revenues on providing goods and services for households and on transfer payments to households. In addition, a carbon price can be imposed on all or a subset of GHG emissions, with the revenues raised redistributed back to households via lump-sum transfers. Equilibrium is obtained through a series of markets—for both factors of production and goods and services—that determine prices so that supply equals demand, firms earn economic profit, and income balances.

Growth in population and economic activity, as measured by GDP, are the key drivers of changes over time. For population growth, a central estimate from the United Nations (UN 2019) is used, which projects that the world population will increase from 7.8 billion in 2020 to 9.7 billion in 2050. The fastest growth is expected to occur in Africa, the Middle East, and Australia/New Zealand, where the model assumes average annual population growth rates of 2.1%, 1.2%, and 1%, respectively, over the 2020–50 period. Some countries—such as Japan, Russia, China, and South Korea—are projected to experience negative population growth over this period. While the scenario projections from the model are up to 2100, in this study we focus on 2030 as the period for which most of the NDCs for the Paris Agreement are currently specified.

Forecasts from the International Monetary Fund (IMF 2021) are adopted for near-term GDP growth. Assumptions about long-term productivity growth are taken from the MIT Joint Program on the Science and Policy of Global Change (MIT Joint Program 2021), leading to an assumed average annual growth rate of world GDP of about 2.5% for the 2020–30 period. We assume slower growth in advanced economies than in developing and emerging economies. For example, GDP growth in 2030 is projected to be 1.7% in the US, 2.4% in Canada, and 1.4% in Europe, but in the same period India grows by 5.8%, Africa by 4%, and China by 3.8%. Annual average GDP growth rates for all model regions and all periods in the baseline scenario are provided in Chen *et al.* (2022b). While we assume the same region-specific population growth in all scenarios, GDP growth is affected by economic and climate policies and as such is different under different policy scenarios.

Table 5 Sectors in the MIT's Economic Projection and Policy Analysis model

Sectors	Electricity subsectors
Cement	Coal electricity
Iron and steel	Natural gas electricity
Other energy-intensive	Petroleum electricity
Other manufacturing	Nuclear electricity
Services	Hydro electricity
Crops	Wind electricity
Livestock	Solar electricity
Forestry	Biomass electricity
Food processing	Wind combined w/ gas backup
Coal production	Wind combined w/ biofuel backup
Oil production	Coal with CCS
Oil refining	Natural gas with CCS
Natural gas production	Advanced nuclear electricity
Electricity	Advanced natural gas
Private transportation: gasoline and diesel vehicles	
Private transportation: electric vehicles	
Commercial transportation	
First-generation biofuels	
Advanced biofuels	
Oil shale	
Synthetic gas from coal	

Note: CCS is carbon capture and storage.

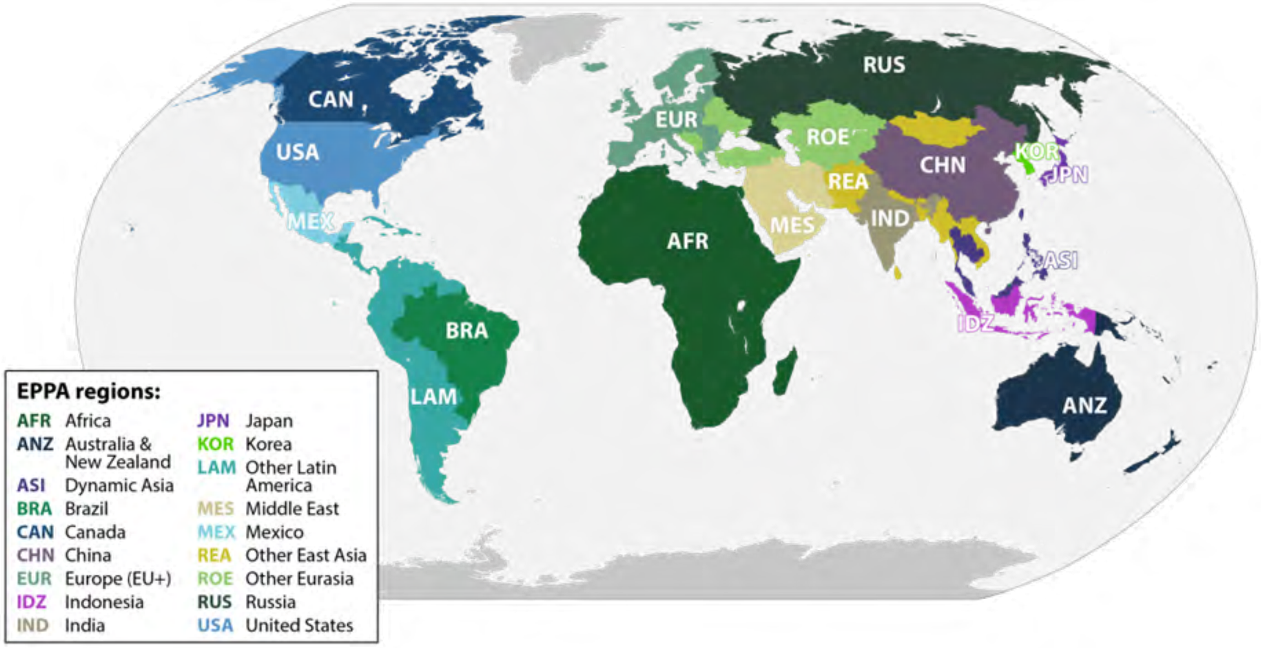

Figure 8 Regions in MIT's Economic Projection and Policy Analysis model

Appendix B: Tariff/rebate rates

Figure 9 and Figure 10 show the average import tariff and export rebate rates imposed on the imports from all other origins to Canada, Europe, and the US and exports from these three regions to all destinations as an example. These import tariff rates and export rebates are calculated based on carbon price differentials across regions and embodied emissions (as explained in section 3.3).

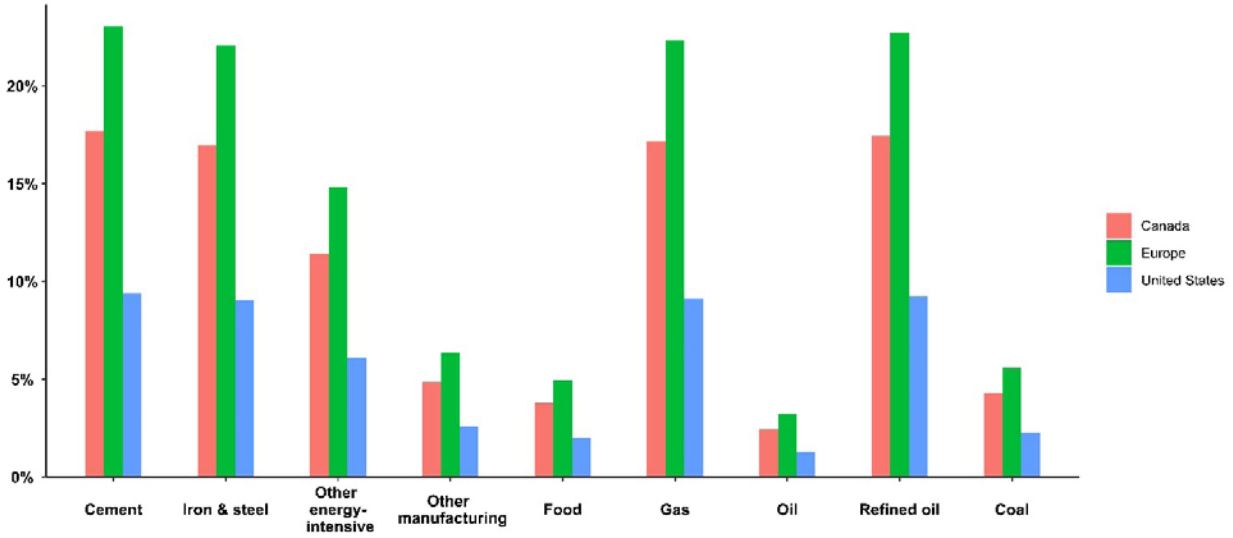

Figure 9 Average ad valorem tariff rates imposed on imports (%)

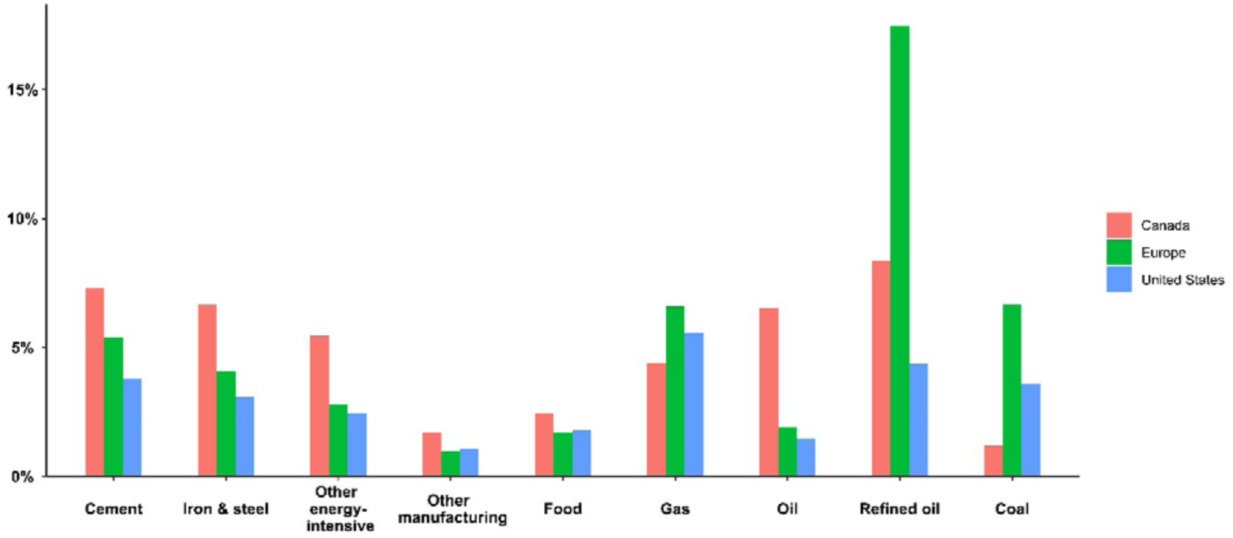

Figure 10 Average ad valorem export rebates imposed on exports (%)

Appendix C: Modelling details

Emission targets

The following table shows the emission ratio targets that are used in the MIT-EPPA model to generate different scenarios. **Table 6** shows emission targets (relative to 2015 levels) that were used to build the uncoordinated and BCA scenarios. These emission ratios are based on information from different sources such as Climate Action Tracker, NGFS phase 3 climate scenario release, and MIT Global Change Outlook (MIT Joint Program on the Science and Policy of Global Change 2021).

Table 6 NDC emission targets (relative to 2015 levels)

	USA	CAN	MEX	JPN	EUR	KOR
2020	0.894	0.899	0.885	0.854	0.833	0.962
2025	0.749	0.756	0.834	0.735	0.710	0.808
2030	0.604	0.613	0.829	0.616	0.587	0.655

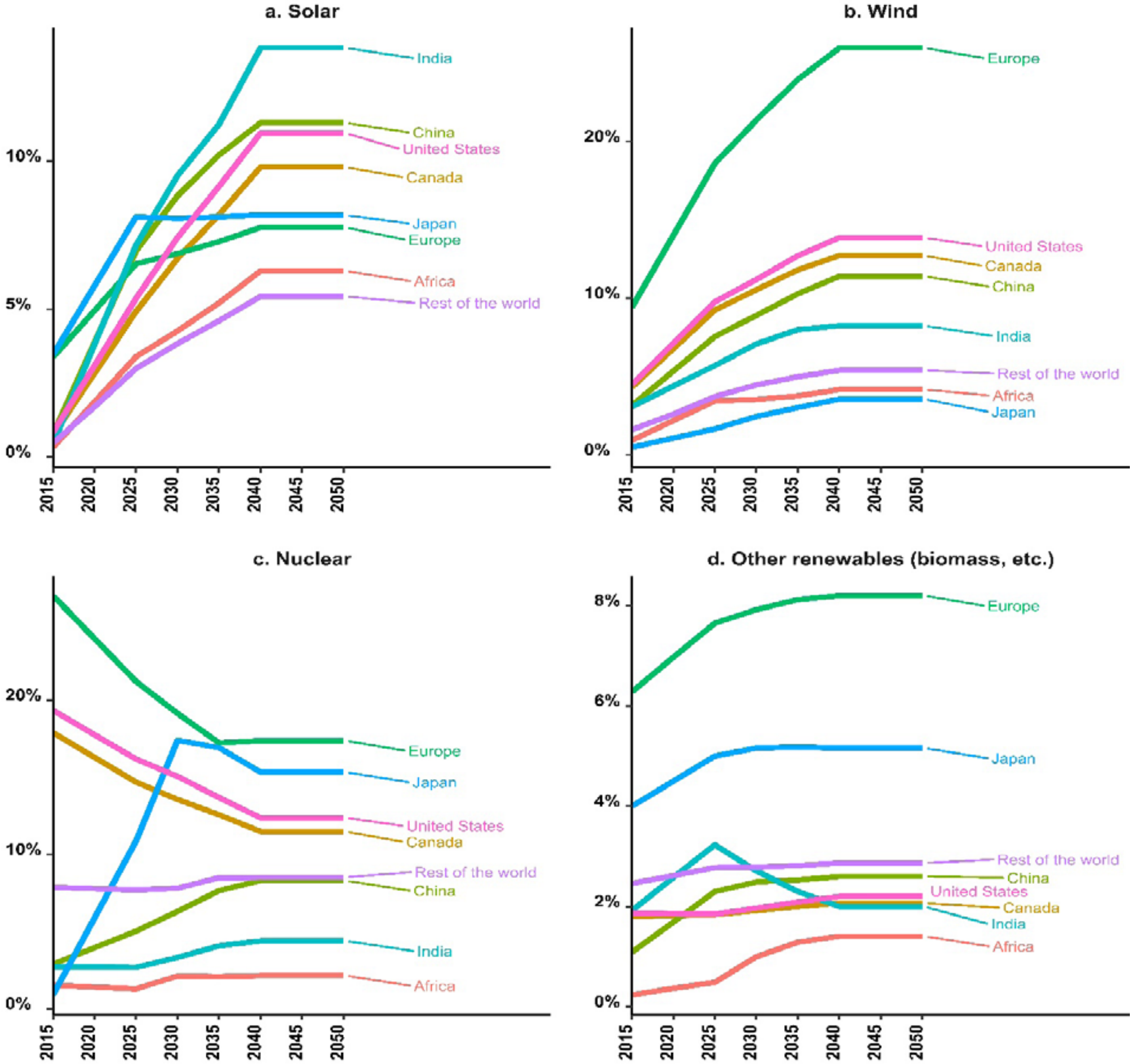

Figure 11 Renewable shares in total electricity generation, by type and region based on IEA's World Energy Outlook (2019)

Appendix D: More detailed modelling outputs

We also explore the scenarios in which import tariffs cover all the sectors and are combined with export rebates (i.e., full | tariffs and rebates). In addition, all the cases of sectoral coverage and export rebates are examined when allowances are replaced with BCAs. Table 7 shows the results from the complete set of scenarios under different design features.

Table 7 Cumulative (2020–30) impacts of different BCA design features relative to baseline

Scenarios	Carbon leakage rate	Domestic market share	Foreign market share	Welfare
Units	*percentage*	*percentage point change*	*percentage point change*	*percentage changes in equivalent variation*
Uncoordinated (No BCA)	6.1	-0.43	-0.05	-0.67
Uncoordinated with allowances (No BCA)	4.38	0.12	-0.03	-0.78
Combining allowances with BCAs				
Allowances + BCA (partial I tariffs only)	-1.07	0.52	0.04	-0.71
Allowances + BCA (full I tariffs only)	-1.16	1.01	0.04	-0.71
Allowances + BCA (partial I tariffs & rebates)	-1.85	0.55	0.08	-0.78
Allowances + BCA (full I tariffs & rebates)	-1.17	0.57	0.08	-0.8
Replacing allowances with BCAs				
BCA (partial I tariffs only)	0.75	0.01	0.02	-0.59
BCA (full I tariffs only)	0.66	0.5	0.02	-0.59
BCA (partial I tariffs & rebates)	0.07	0.03	0.05	-0.65
BCA (full I tariffs & rebates)	0.7	0.04	0.05	-0.66

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