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Using the CBO-EPPA Model to Analyze Carbon Import Tariffs and Export Rebates

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Abstract

In this working paper, we analyze the effects of carbon import tariffs and export rebates (implemented along with a carbon tax) on sectoral output, trade, and carbon dioxide emissions and compare them with the effects of a carbon tax alone. For that analysis, we used a modified version of the Massachusetts Institute of Technology's Economic Projection and Policy Analysis (EPPA) model, known as CBO-EPPA. This paper provides an overview of that model and outlines its strengths and limitations.

Using CBO-EPPA, we estimate that implementing a carbon tax would reduce the output of energy-intensive and trade-exposed (EITE) sectors in 2050 by 2.6 percent, would decrease those sectors' exports in 2050 by 2.2 percent, and would increase EITE product imports in 2050 by 0.2 percent. By contrast, implementing both a carbon import tariff and an export rebate along with a carbon tax would increase the output of affected sectors in 2050 by 0.2 percent, would increase those sectors' exports in 2050 by 4.8 percent, and would decrease EITE product imports in 2050 by 2.4 percent. Although those estimates account for key dynamics in global energy markets, they remain uncertain because of potential variations in policy design and market responses that the model cannot fully capture.

In addition to detailing those results, this paper discusses how carbon import tariffs and export rebates could be challenged under the rules in World Trade Organization treaties.

Keywords: carbon dioxide, climate, international trade, tax

JEL Classification: F13, F18, Q56, Q58

Notes

Numbers in the text, tables, and figures may not add up to totals because of rounding.

Unless otherwise specified, all dollar amounts are expressed in 2014 dollars, reflecting the base year of the CBO-EPPA model.

“Emissions” refers to carbon dioxide emissions unless otherwise specified.

In the illustrative policy cases, carbon import tariffs and export rebates are implemented along with a carbon tax.

Contents

Introduction

To analyze the effects of carbon import tariffs and export rebates (implemented along with a carbon tax) on sectoral output, trade, and carbon dioxide (CO_2) emissions, we adopted and modified the Economic Projection and Policy Analysis (EPPA) model from the Massachusetts Institute of Technology's (MIT's) Center for Sustainability Science and Strategy.[1] That model is an open-source, computable general equilibrium model of the world economy that projects economic and emissions outcomes over several decades. The version of EPPA that we adapted for this paper is not currently available to the public, but previous versions of the model are publicly available.[2] This working paper provides a brief overview of the EPPA model along with a discussion of the model's strengths and limitations.

We used EPPA to analyze the economic and emissions effects of illustrative policy cases in which carbon import tariffs and export rebates are implemented along with a carbon tax. Carbon import tariffs impose a tax on imports based on the amount of CO_2 released during those imports' production and supply chain processes; the tax is calculated so that it is equal to the carbon tax placed on domestic producers. Carbon export rebates refund the carbon taxes paid during the domestic production and supply of certain exports. Together, carbon import tariffs and export rebates equalize the tax costs for domestic and foreign producers in their destination markets. Under such a policy, known as a border adjustment, foreign firms that produce U.S. imports pay the same tax rate on CO_2 emissions as competing U.S. producers, and U.S. producers that export to other countries pay the same tax rate as competing foreign producers.

The use of import tariffs and export rebates in conjunction with a carbon tax has a precedent in other noncarbon policies such as value-added taxes in Europe and certain excise taxes in the United States. Furthermore, carbon import tariffs and export rebates like the ones analyzed here have been included in several Congressional bills designed to price CO_2 emissions, such as the MARKET CHOICE Act (H.R. 3338) and America's Clean Future Fund Act (S. 2712), each of which would impose a carbon tax along with carbon import tariffs and export rebates.[3]

Finally, we discuss how trading partners might challenge carbon import tariffs or export rebates at the World Trade Organization (WTO) and how the United States might respond. To assess possible scenarios, we reviewed analyses by experts in trade law.

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[1] Yen-Heng Henry Chen and others, "A Multisectoral Dynamic Model for Energy, Economic, and Climate Scenario Analysis," *Low Carbon Economy*, vol. 13, no. 2 (June 2022), https://doi.org/10.4236/lce.2022.132005.

[2] We adapted version 7 of the EPPA model. Version 6 can be downloaded at https://cs3.mit.edu/research/research-tools/human-system-model/download.

[3] Sec. 102 of the MARKET CHOICE Act, H.R. 3338, 119th Cong. (2025); and sec. 4695 of America's Clean Future Fund Act, S. 2712, 119th Cong. (2025).

Overview of the EPPA Model

EPPA is a multiregion and multisector model of the global economy containing 18 world regions and 16 industry sectors (see Table 1). The model has been used in various studies to analyze a range of climate and technology policies (such as carbon taxes and regulatory standards), as well as carbon capture and sequestration technology.[4] This section provides an overview of EPPA's structure and discusses its main strengths and limitations.

Model Structure

For this paper, we adapted a version of the EPPA model, MIT-EPPA7, developed by MIT's Center for Sustainability Science and Strategy. The model is designed to analyze how climate and energy policies affect the economy, trade, and greenhouse gas (GHG) emissions over time.

EPPA's base year is 2014. The model solves in five-year increments from 2015 to 2100. For each of those five-year increments, the model calculates the optimal economic decisions for households, governments, and businesses—such as how much to produce, consume, save, and invest—on the basis of the prices observed during that five-year period. As part of that process, EPPA determines a set of prices that balance the quantity supplied and demanded across markets. That means that all the goods and services consumers demand are supplied by firms and all the labor and capital demanded by firms are supplied by households. Because of its long time horizon, the model shows how policies and economic conditions shape long-term trends in economic outcomes and GHG emissions.

EPPA represents three economic groups in each geographic region: households, governments, and businesses. Households own the factors of production: labor, land, natural resources, and capital. The government levies taxes and collects revenues, which in this analysis are transferred back to households in lump sums. The model simulates how those resources would be used by businesses given constant returns to scale, perfectly competitive firms, and price-taking behavior. Although there is some evidence that exporting firms exhibit increasing returns to scale and that international markets are not perfectly competitive, restructuring the model to account for those features would make it less computationally tractable; for that reason, we chose not to incorporate those modeling choices. The model also accounts for international trade by modeling similar goods from different countries as not perfectly substitutable. Over time, the model adjusts for the adoption of new technology and improvements in energy efficiency by incorporating external projections of future reductions in technology costs and trends in input efficiency.

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[4] For a list of recent studies that have used the EPPA framework, see MIT Center for Sustainability Science and Strategy, "Peer-Reviewed Research" (accessed January 23, 2026), https://cs3.mit.edu/publications/peer-reviewed.

EPPA relies on data from the Global Trade Analysis Project (GTAP) Power 10 database, which has 2014 as its base year.[5] EPPA groups the GTAP data into 18 world regions and 16 industry sectors. Some regions are individual countries, such as the United States, whereas others comprise multiple countries, such as the region of Africa. The GTAP database provides comprehensive information about prices, consumption, production, trade flows, and capital flows across all regions, which is essential for calibrating parameters in the EPPA model. The base year is 2014 and not a more recent year because of the time and effort required to compile and reconcile the extensive data needed for the calibration. The model tracks CO_2 emissions from the burning of fossil fuels, using specific emissions rates for each fuel type. It also tracks GHG emissions from industrial processes, such as steel production.

A more recent version of the GTAP database, GTAP-11, is available but is not used in our version of the EPPA model. That new database has a base year of 2017 and incorporates more recent economic activity as well as updated national input-output tables and revised trade, energy, and emissions data. However, EPPA's GTAP-10 database, which MIT combines with detailed information from the International Energy Agency (IEA) about energy and emissions, allows for a more accurate accounting of energy use and emissions. (MIT has not yet aligned GTAP-11 with IEA's data.)

Main Strengths and Limitations of the Model

EPPA has several strengths and limitations. Strengths of the model include detailed sectoral and regional disaggregation, comprehensive tracking of GHG emissions, and comprehensive data sources. Those features make it particularly useful for assessments of carbon import tariffs and export rebates, which require a representation of trade flows and existing environmental policies of trading partners. Limitations of EPPA include the model's time scale (which poses challenges for analyzing near-term policy effects), its limited representation of firm-level heterogeneity, and its lack of representation of forward-looking behavior.

Strengths of the Model. EPPA's first strength is its sectoral and regional disaggregation, which allows for a comprehensive assessment of how policies interact across interlinked sectors and regions within a unified framework that reflects economywide resource and budget constraints. EPPA separately models 16 economic sectors, allowing users to estimate energy consumption, CO_2 emissions, economic output, and international trade flows by sector, as well as economic interactions between sectors. That disaggregation allows for assessments of how certain sectors of the economy might react differently to specific policies, such as a price on CO_2 emissions or sector-specific carbon import tariffs or export rebates like those analyzed in this paper. EPPA's regional disaggregation represents 18 countries and regions around the world. That regionality

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[5] Maksym Chepeliev, "GTAP-Power Data Base: Version 10," *Journal of Global Economic Analysis*, vol. 5, no. 2 (December 2020), https://doi.org/10.21642/JGEA.050203AF.

allows the model to track exports and imports between multiple origins and destinations as well as how carbon import tariffs and export rebates are affected by the emissions policies of key foreign trading partners. For instance, if a product comes from a country with more stringent climate policies than the United States, policymakers might choose to exempt that product from carbon import tariffs, which highlights the importance of capturing international policy differences.

A second key strength of the model is its ability to track GHG emissions alongside important economic factors. EPPA captures multiple sources of GHG emissions—including industrial processes, fuel combustion, land use, and agriculture—across sectors and regions. The model also estimates emissions for each stage of a supply chain, making it particularly useful for an analysis of carbon import tariffs and export rebates, which must account for all of the emissions embedded in traded goods. Along with emissions, the model tracks various economic indicators, including sector output, trade flows, consumption, investment, employment, wages, capital stocks, and interest rates. Those economic indicators help CBO assess how climate and energy policies might affect different parts of the economy.

A third key strength of EPPA is its use of a comprehensive data source, GTAP, which tracks trade flows, production, consumption, and the use of goods and services across industries. GTAP organizes that information within a broader framework of the global economy, ensuring that all data are consistent. For a large general equilibrium model like EPPA to solve, it must be "balanced"; GTAP's database achieves that balance by ensuring that all expenditures match income. That allows for analysis of economic activity that is internally consistent.

Limitations of the Model. One of EPPA's limitations is its time scale. Because the model was designed to project economic activity and GHG emissions through the end of the century, it operates in five-year increments. That long-term focus is useful for analyzing the effects of policies over decades. However, CBO frequently evaluates policies on the basis of their short- to medium-term effects, usually within a 10-year window.[6] Because of its extended time scale, the model is not well suited for capturing short-term effects and cannot provide annual estimates of near-term impacts.

A second limitation relates to how EPPA models firms' behavior and trade. Like many general equilibrium models, EPPA uses representative firms and Armington trade structures, which are well suited for capturing broad market responses but do not capture firm-level heterogeneity.[7] As

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[6] For example, a 10-year window was used in Congressional Budget Office, *The Budget and Economic Outlook: 2026 to 2036* (February 2026), www.cbo.gov/publication/61882.

[7] The Armington trade structure treats goods from different origins as imperfect substitutes. A constant elasticity of substitution aggregator combines domestic and imported varieties, so shifts in relative prices reallocate demand smoothly instead of driving a full switch to the cheapest source.

a result, the model cannot reflect strategic export responses based on emissions intensity or carbon policy stringency across trade destinations—for example, reallocations of exports that might occur under certain carbon import tariffs. Although that does not affect EPPA's capacity to evaluate the aggregate impacts of carbon pricing or trade, it limits the model's ability to capture firm-level responses to differences in the application of carbon import tariffs. That limitation has implications for our results, because firms could behave in ways not captured by EPPA. In the section "Sources of Uncertainty," we discuss how that limitation could influence our findings.

A third limitation is that EPPA does not incorporate the effects of forward-looking behavior, which can be important for analyzing some tax policies. The model used in this paper is a recursive dynamic model—that is, one in which agents make myopic decisions on the basis of current-period conditions and extrapolate future states from past outcomes. That contrasts with a forward-looking (perfect foresight) dynamic model, in which agents optimize their decisions to consume and save over a multiperiod horizon with perfect knowledge about future prices, policies, and constraints. Although the two modeling frameworks capture different aspects of dynamic behavioral responses, neither fully reflects the complexities of firms' and households' decision-making. Furthermore, some researchers have developed a forward-looking version of EPPA and found that its results do not differ substantially from those of the standard recursive dynamic framework.[8] Thus, we have adopted the recursive dynamic framework primarily for its computational tractability and because it adequately captures how agents respond to the policies considered in our analysis.

Analyzing Carbon Import Tariffs and Export Rebates Using CBO-EPPA

Using CBO-EPPA, our modified version of the EPPA model, we conducted a scenario analysis to project the economic and CO_2 emissions effects of carbon import tariffs and export rebates (implemented in addition to a carbon tax). We compare those effects with the effects of a carbon tax alone to show how those policies influence the competitiveness of domestic firms.

The policies analyzed in this paper are presented in reference to a base case. The base case represents a scenario that is generally consistent with CBO's projections of domestic and international economic and population growth, domestic and international primary energy use, and domestic CO_2 emissions. Calibrations to align the model with those projections are described in Appendix A. In summary, our calibrations included the following:

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[8] Mustafa Babiker and others, *A Forward-Looking Version of the MIT Emissions Prediction and Policy Analysis (EPPA) Model* (MIT Joint Program on the Science and Policy of Global Change, May 2008), http://hdl.handle.net/1721.1/44618.

- Projections of domestic economic growth are drawn from CBO's *2023 Long-Term Budget Outlook*.[9]
- Projections of energy use come from the Energy Information Administration's (EIA's) *Annual Energy Outlook 2023* reference case.[10]
- Projections of emissions in the United States come from CBO's Carbon Revenue Model (which is used to produce the agency's benchmark projection of greenhouse gas emissions), and projections of global emissions come from EIA's *International Energy Outlook 2023*.[11]

The base case reflects projections of energy use and parameters for economic relationships that are more current than EPPA's original projections. However, they do not explicitly account for some recently enacted laws and policies, such as the investment tax credit and the production tax credit for solar and wind electricity generation or tax credits for carbon capture and storage. We indirectly account for some of the costs that those policies impose by applying taxes and subsidies to energy use so that the base case reflects our energy projections. EIA's *Annual Energy Outlook 2023* reference case incorporates all energy policies in place as of November 2022. By solving for the tax and subsidy rates that would reproduce EIA's projected energy use in our model, we derive the implicit policy parameters consistent with those projections. That method allows us to maintain the tractability of the model and include some of the regulatory costs imposed on energy markets. In that sense, our model reflects laws and policies that affect energy use and were in place as of November 2022, the year before our energy projections were generated.[12]

Additionally, tariff policies that have been implemented through executive action since 2018 have not been included in the base case.[13] Because we are analyzing the effects of illustrative carbon import tariffs and export rebates and not projecting the effects of current

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[9] Congressional Budget Office, *The 2023 Long-Term Budget Outlook* (June 2023), www.cbo.gov/publication/59014.

[10] Energy Information Administration, *Annual Energy Outlook 2023* (March 2023), www.eia.gov/outlooks/archive/aeo23.

[11] Congressional Budget Office, *CBO's Benchmark Projection of Greenhouse Gas Emissions* (November 2024), www.cbo.gov/publication/60862; and Energy Information Administration, *International Energy Outlook 2023* (October 2023), www.eia.gov/outlooks/ieo.

[12] The model indirectly includes the energy provisions in the 2022 reconciliation act (Public Law 117-169) but not the recissions of those provisions in the 2025 reconciliation act (P.L. 119-21). Updating the model to include the projections from EIA's *Annual Energy Outlook* for 2025 would not improve the results because those projections were published in March of that year and do not incorporate the effects of the 2025 reconciliation act.

[13] That includes tariff policies implemented in 2018 and 2019 related to section 232 of the Trade Expansion Act of 1962 and section 301 of the Trade Act of 1974. The rates of some of those section 301 tariffs were later increased in 2024. Additional tariffs were implemented in 2025 through executive action under the International Emergency Economic Powers Act.

policy, those tariff policies lie outside the scope of this paper. In the results section, we provide a qualitative analysis of how such policies might affect our results.

Policies Analyzed

We used three illustrative policy scenarios to compare the economic and emissions effects of carbon import tariffs and export rebates. In the first policy case, a carbon tax is implemented without a carbon import tariff or an export rebate to illustrate how placing a price on CO_2 emissions would reduce the competitiveness of domestic firms in relation to foreign firms. In the second and third cases, import tariffs and export rebates are implemented in addition to the carbon tax to demonstrate how such policies could alleviate those competitiveness effects.

Carbon import tariffs and export rebates are designed to equalize carbon tax costs on the basis of a good's destination, ensuring that producers face comparable costs for CO_2 emissions regardless of where their goods originate. A similar structure exists in value-added taxes, which are also destination-based and work in a similar way: Importers are taxed at the same rate as domestic producers, and exporters are refunded for any taxes they have paid. That approach ensures that tax treatment is consistent across borders and does not distort trade flows.

We simulated the following three policy scenarios for this paper.

- **Carbon tax case.** In this scenario, we represented an economywide price on CO_2 emissions through a carbon tax. The rate of that carbon tax matches what was used in CBO's *Options for Reducing the Deficit: 2025 to 2034*, starting at \$25 (in 2025 dollars) per metric ton of CO_2 emissions in 2025 and increasing annually by 5 percent.[14] This policy case does not include a carbon import tariff or an export rebate, and it is intended to serve as a point of comparison for the scenarios that follow.
- **Carbon import tariff case.** This scenario includes both the carbon tax described above and a carbon import tariff on imported goods, so that international producers face a CO_2 emissions price that matches the rate applied to U.S. producers. The carbon import tariff rate is calculated on the basis of the embedded direct and indirect CO_2 emissions content of an international trade partner's good, multiplied by the U.S. carbon tax rate.[15] (Direct emissions are released during on-site production, whereas indirect emissions result from the production of upstream inputs.) Policymakers could structure carbon import tariffs to account for emissions pricing policies in the country of origin by subtracting the emissions price that the producer paid. However, this study does not account for emissions pricing policies outside

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[14] Congressional Budget Office, *Options for Reducing the Deficit: 2025 to 2034* (December 2024), p. 84, www.cbo.gov/publication/60557.

[15] For example, if an imported good embodies 0.5 metric tons of CO_2 emissions and the U.S. carbon tax rate is \$25 per metric ton of CO_2, the resulting tariff on that good is \$12.50 (0.5 multiplied by \$25).

the United States, and in this scenario the carbon import tariff is applied to all U.S. trading partners.[16]

- **Carbon import tariff and export rebate case.** This scenario is identical to the previous one but includes an export rebate as well. That export rebate is provided to U.S. producers to offset the amount that those firms have paid for the CO_2 emissions generated by their exports. The export rebate is calculated on the basis of the direct and indirect CO_2 emissions content of an exported good, multiplied by the U.S. carbon tax rate, using an approach analogous to the one used in the previous scenario.[17] The carbon import tariff is applied to all U.S. trading partners, and the export rebate is applied to U.S. producers regardless of the destination of their exports.

The embedded direct and indirect CO_2 emissions content of all goods changes over time because of improvements in energy efficiency and production processes. Because the intensity of those emissions varies over time and differs across regions, so do the resulting rates for carbon import tariffs and export rebates.

In this analysis, both carbon import tariffs and export rebates are applied only to certain sectors of the economy. The sectors are those with both high emissions intensity and significant trade exposure, often referred to as energy-intensive and trade-exposed (EITE) sectors, which are most at risk of reduced output under a CO_2 pricing policy. In CBO-EPPA, there are four EITE sectors:

- **Energy-intensive manufacturing.** An aggregation of sectors, including chemical, paper, printing and related support, and plastics and rubber products.
- **Nonmetallic minerals.** Includes cement and glass production, along with related products.
- **Petroleum and coal products.** Includes refined petroleum-based products, such as motor gasoline, lubricants, and asphalt, and a small number of coal-based products, such as coke.
- **Primary metals.** Includes iron and steel production.

We also analyzed two sensitivity scenarios. In the main analysis, no countries are exempt from the carbon import tariffs or the carbon export rebates. However, real-world policies could be structured to exempt certain countries that have their own CO_2 emissions pricing policies in place. One region in the EPPA model that might qualify for such an exemption is the European Union, which has a cap-and-trade system for CO_2 emissions whose recent prices have been higher than the tax of $25 per metric ton of CO_2 considered here. In the first sensitivity scenario, we exempt the European Union from both carbon import tariffs and export rebates to investigate

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[16] The rates for carbon import tariffs and export rebates are calculated solely on the basis of the domestic carbon tax rate. Appendix B includes a sensitivity analysis in which we account for emissions pricing policies in the European Union.

[17] As in the carbon import tariff case, we apply only the domestic carbon tax rate because the model does not include emissions pricing data from other countries.

how those exemptions affect the results. The second sensitivity scenario expands the coverage of carbon import tariffs and export rebates to two additional sectors, agriculture and mining. Although most proposed policies affect only the EITE sectors listed above, future policies might expand the sectoral coverage of carbon import tariffs or export rebates. The results of those simulations are presented in Appendix B.

Results

We analyzed the projected effects of the three illustrative policy scenarios on U.S. EITE sectors and compared them with outcomes in the base case. Key results include the following:

- **Output.** In 2050, the output of EITE sectors is 2.6 percent lower in the carbon tax case than in the base case. When carbon import tariffs and export rebates are applied, the effect of the carbon tax on output is reduced or even reversed: The output of EITE sectors in 2050 decreases by 1.6 percent in the carbon import tariff case and increases by 0.2 percent in the carbon import tariff and export rebate case, compared with the base case.
- **Trade.** In the carbon tax case, EITE sector exports are lower by 2.2 percent and EITE product imports are higher by 0.2 percent in 2050, compared with the base case. In the carbon import tariff case, EITE sector exports decrease by 3.7 percent and EITE product imports drop by 1.9 percent in 2050, compared with the base case. In the carbon import tariff and export rebate case, EITE sector exports rise by 4.8 percent and EITE product imports decline by 2.4 percent, compared with the base case.
- **Emissions.** In the carbon tax case, total U.S. CO_2 emissions in 2050 are lower than they are in the base case by 24 percent, or 1,014 million metric tons (MMT); emissions from EITE sectors are also lower by 24 percent, or 238 MMT. In the carbon import tariff case, CO_2 emissions from EITE sectors decrease by 235 MMT relative to the base case but remain slightly higher than in the carbon tax case—by 0.4 percent, or 3 MMT. In the carbon import tariff and export rebate case, emissions from those sectors decline by 223 MMT relative to the base case, which makes them about 2 percent higher than in the carbon tax case.
- **Carbon leakage.** In the carbon tax case, CO_2 emissions from countries outside the United States increase, offsetting about 8 percent of the CO_2 emissions reductions in the United States over the 2030–2050 projection period. That rate falls to 5 percent in the carbon import tariff case and 4 percent in the carbon import tariff and export rebate case.

Sectoral Output. In the carbon tax case, the output of EITE sectors declines by an average of 2.4 percent over the projection period, compared with the base case (see Table 2). The petroleum and coal products sector experiences the largest reduction in output, declining by 5.7 percent in 2030 and by nearly 10 percent in 2050. Other EITE sectors experience a reduction in output of about 1 percent to 2 percent, on average, over the projection period.

When a carbon import tariff or an export rebate is implemented in addition to a carbon tax, the decline in EITE output is moderated. Those policies help establish competitive neutrality between domestic producers and foreign competitors not subject to a carbon tax by applying a carbon import tariff on imported goods based on their embodied emissions and, in the case of an export rebate, by providing a refund for the carbon costs of exports. As a result, the competitive pressure on U.S. EITE sectors is reduced. In the case of combining a carbon import tariff with a carbon tax, total EITE output over the projection period declines by 1.6 percent relative to the base case, which is a smaller decline than in the carbon tax case. When a carbon import tariff and export rebate are combined with a carbon tax, total EITE output decreases, on average, by 0.4 percent relative to the base case; with a carbon tax alone, it decreases by 2.4 percent.

The primary metals sector exhibits a notable increase in output in both scenarios. In the carbon import tariff case, the tariff provides a competitive advantage for U.S. producers that are typically less emissions-intensive than their international counterparts. Over the past two decades, the primary metals sector has become substantially less emissions-intensive, largely because steel production methods have become much more energy efficient.[18] That sector shows an average increase in output of 0.6 percent over the projection period, whereas total EITE sector output declines by 1.6 percent. In the carbon import tariff and export rebate case, output in the primary metals sector increases by an average of 1.9 percent over the projection period, whereas total EITE sector output declines by 0.4 percent. The relatively lower emissions intensity of the primary metals sector gives it a competitive advantage in both scenarios, allowing the sector to expand more quickly than sectors that are more emissions-intensive.

Trade. In the carbon tax case, EITE product imports increase by 0.1 percent, on average, over the projection period, and EITE sector exports decrease by 1.9 percent (see Table 3). That change in trade reflects the reduced competitiveness of U.S. producers in relation to foreign competitors.

Carbon import tariffs and export rebates mitigate some of those effects. We find that when a carbon import tariff is added, EITE product imports fall by 1.9 percent and EITE sector exports fall by 3.7 percent in 2050, relative to the base case. Applying a tariff without an export rebate improves the competitiveness of import-competing industries, decreasing imports, but it also reduces the purchasing power and competitiveness of exporting industries, leading to lower exports. Combining a carbon tax with a carbon import tariff and an export rebate results in a decrease in EITE product imports of 2.4 percent and an increase in EITE sector exports of 4.8 percent in 2050 relative to the base case, reversing the trade effects from a loss of competitiveness in the carbon tax case.

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[18] Specifically, steel manufacturers in the United States have switched from basic oxygen furnaces to electric arc furnaces, which use less energy to produce each unit of steel. See Congressional Budget Office, *Emissions of Greenhouse Gases in the Manufacturing Sector* (February 2024), p. 11, www.cbo.gov/publication/59695.

Almost all EITE sectors have increased imports and reduced exports in the carbon tax case. The exception is the petroleum and coal products sector, which experiences a reduction in imports of 3.4 percent in 2050. That drop in imports occurs because the carbon tax reduces demand for refined petroleum products.

Emissions. In the base case, total U.S. CO_2 emissions increase from 4,199 MMT in 2030 to 4,245 MMT in 2050. By the end of the projection period, the EITE sectors account for 23 percent of that total, or 982 MMT (see Table 4).

In the carbon tax case, total U.S. CO_2 emissions are 11 percent (or 477 MMT) lower in 2030 and 24 percent (or 1,014 MMT) lower in 2050. Similarly, CO_2 emissions in the combined EITE sectors are lower by 7 percent (or 65 MMT) in 2030 and by 24 percent (or 238 MMT) in 2050.

The addition of a carbon import tariff and an export rebate to a carbon tax reduces the CO_2 emissions of U.S. EITE sectors relative to the base case, though by less than a carbon tax alone. That is primarily because of expanded production in those sectors as a result of the import tariff and export rebate. In 2050, CO_2 emissions in the carbon import tariff case decrease by 235 MMT relative to the base case, or about 1 percent (or 3 MMT) more than with a carbon tax alone. Similarly, when a carbon tax is combined with an import tariff and export rebate, CO_2 emissions in 2050 are 23 percent (or 223 MMT) lower than in the base case and 2 percent (or 15 MMT) higher than in the carbon tax case.

Carbon Leakage. Although a domestic carbon tax would reduce U.S. CO_2 emissions, it could cause an offsetting increase in CO_2 emissions abroad, a phenomenon known as carbon leakage. Carbon leakage occurs when a unilateral emissions pricing policy in one region incentivizes firms to shift production to other regions. In this paper, the carbon leakage rate is defined as the ratio of the increase in international (non-U.S.) CO_2 emissions to the reduction in U.S. CO_2 emissions. A carbon leakage rate of zero indicates the absence of carbon leakage, meaning that as emissions fall in the United States, emissions abroad do not increase. Conversely, a carbon leakage rate of 100 percent indicates that for every reduction in U.S. emissions, an equivalent increase occurs in non-U.S. emissions, resulting in no overall reduction in global emissions.

In the carbon tax case, the United States reduces domestic CO_2 emissions by 1,014 MMT in 2050. In that year, emissions in the rest of the world increase by 74 MMT, resulting in a leakage rate of 7 percent. The average leakage rate is 8 percent over the 2030–2050 period. That estimate is just below the lower end of the typical range reported in the literature.[19] The leakage rate reaches 9 percent in 2030, peaks at 10 percent in 2035, and then gradually declines to 7 percent

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[19] For a recent review of the literature, see Justin Caron, "Empirical Evidence and Projections of Carbon Leakage: Some, but Not Too Much, Probably," in Michael Jakob, ed., *Handbook on Trade Policy and Climate Change* (Edward Elgar Publishing, 2022), pp. 58–74, https://doi.org/10.4337/9781839103247.

by 2050 because of continual reductions in the CO_2 emissions intensity of global economies toward the end of the projection period.

Carbon import tariffs and export rebates mitigate the carbon leakage associated with a CO_2 emissions pricing policy. In the carbon import tariff case, the average carbon leakage rate falls to 5 percent over the 2030–2050 period; that rate falls to 4 percent in the carbon import tariff and export rebate case. In 2050, U.S. CO_2 emissions are reduced by nearly the same amount in the carbon tax case, the carbon import tariff case, and the carbon import tariff and export rebate case (by 1,014 MMT, 1,025 MMT, and 1,020 MMT, respectively). However, in 2050, CO_2 emissions from other countries increase by 74 MMT in the carbon tax case. The increase in those emissions is smaller in the carbon import tariff case (39 MMT) and the carbon import tariff and export rebate case (44 MMT).

Carbon leakage typically occurs through two primary channels: competitive leakage and fuel price leakage. Competitive leakage occurs when suppliers in regions with less stringent climate regulations gain a competitive advantage in international markets. If domestic climate policies increased production costs for U.S. industries, imports from less regulated regions would likely rise, leading to higher global CO_2 emissions. That type of leakage is prevalent in sectors with high exposure to international trade and is associated with output losses, as domestic production decreases while foreign production increases.

Fuel price leakage occurs when a reduction in domestic demand for fossil fuels—resulting from a policy such as a carbon tax—leads to a drop in global fuel prices. Those lower prices encourage increased consumption abroad, thereby offsetting domestic reductions in CO_2 emissions. We find that fuel price leakage accounts for about half of the total carbon leakage in the carbon tax case.

Research suggests that nearly all leakage is either competitive leakage or fuel price leakage.[20] If carbon import tariffs and export rebates fully eliminated competitive leakage, then any remaining leakage in the carbon import tariff and export rebate case would be fuel price leakage. In that case, the reported leakage rate could be interpreted as a measure of fuel price leakage. Carbon import tariffs and export rebates cannot fully eliminate fuel price leakage, particularly because that form of leakage occurs in less traded sectors, such as electric power and transportation, in which those policies have little direct effect.

We identified the sectors that contribute the most to carbon leakage (see Figure 1). In the carbon tax case, about 40 percent of the leakage stems from EITE sectors, mostly because higher domestic production costs from CO_2 pricing cause firms to lose market share to foreign

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[20] Ibid.

competitors in countries with weaker or no emissions policies. That shift in trade patterns results in emissions moving abroad rather than being reduced.

In addition to where goods are produced, how they are produced also affects global emissions. On average, EITE sectors in regions outside the United States are more than twice as emissions-intensive as those in the United States, largely because of their greater use of higher-emitting energy sources such as coal (as opposed to natural gas). A shift in production to those regions would lead to a net increase in global emissions. For example, in the carbon tax case, EITE sector emissions outside the United States increase by 30 MMT in 2050. If foreign production had the same emissions intensity as U.S. production, the increase would be 12 MMT. The additional 18 MMT of carbon leakage reflects the higher emissions intensity of production abroad.

Energy-intensive sectors that are less traded, such as electric power and transportation, experience leakage mostly through the fuel price channel, in which CO_2 pricing lowers domestic demand for fossil fuels, leading to a decline in global fuel prices. Lower fuel prices, in turn, encourage increased fossil fuel consumption in other countries, resulting in increased emissions.

In our analysis, carbon import tariffs and export rebates reduce carbon leakage in EITE sectors by eliminating competitive leakage but are not effective in mitigating fuel price leakage. In 2050, in the carbon tax case, 53 percent of carbon leakage occurs in sectors with low trade exposure, 41 percent in EITE sectors, and 6 percent in other sectors such as services and agriculture that are not as emissions-intensive or as exposed to international trade as EITE sectors.[21] By contrast, in the carbon import tariff case, net carbon leakage in EITE sectors drops to about zero, whereas leakage in less traded sectors declines by only 3 percent. In the carbon import tariff and export rebate case, EITE sector leakage becomes negative, indicating that emissions in those sectors are lower than they are in the base case. However, leakage from less traded sectors is 24 percent higher than in the carbon tax case. That is because carbon import tariffs and export rebates do little to reduce emissions in less traded energy-intensive sectors, such as electric power and transportation, in which leakage is primarily driven by lower global fuel prices rather than trade dynamics.

The regions where the most carbon leakage occurs include some of the United States' principal trading partners: Canada, China, the European Union, India, Latin America, and Mexico (see Figure 2). From 2030 to 2035, the European Union and Canada are the trading partners with the highest carbon leakage. In the European Union, carbon leakage is primarily influenced by

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[21] Those results apply only to the sectors that experience positive leakage (that is, increases in emissions outside the United States). Two sectors in our simulations, natural gas and crude oil, experience negative leakage (reductions in non-U.S. emissions), offsetting about 12 percent of the positive leakage from the other sectors.

competition with U.S. EITE sectors, whereas carbon leakage in Canada is driven by higher natural gas exports to the United States, resulting from increased demand for natural gas in the United States following the implementation of a carbon tax. Over time, carbon leakage in the European Union and Canada declines because of decreasing CO_2 emissions intensities in both regions and because of a reduction in U.S. natural gas imports from Canada. By contrast, leakage in China and Latin America increases over time. As those regions' economies become less emissions-intensive, the effective burden of carbon import tariffs is reduced and their products become more competitive in international markets, thereby resulting in increased production.

The effect of carbon import tariffs and export rebates on carbon leakage varies by region. For instance, in the carbon import tariff and export rebate case, carbon leakage increases in the European Union but declines in China. That disparity stems from differences in carbon import tariff rates that reflect the variation in embodied CO_2 emissions across regions. Specifically, because Chinese products are more emissions-intensive than those produced in Europe, Chinese producers face higher carbon import tariff rates than their European counterparts. That reduces the competitiveness of Chinese products in international markets and causes domestic consumers to switch from Chinese imports to less emissions-intensive European imports.

Sources of Uncertainty

The findings in this paper are subject to five main sources of uncertainty that could affect real-world outcomes.

First, the analytical approach does not account for trade reshuffling, which occurs when firms reallocate their exports in response to tariffs. Because CBO-EPPA uses a single representative firm for each sector in each region, the model does not capture reallocations among heterogeneous firms, even though such behavior is common in real-world markets. For example, if a high-emitting firm that exports to the United States faces a carbon import tariff, that firm might shift its production focus to its domestic market. Similarly, a firm in the same region with lower CO_2 emissions might switch from serving domestic consumers to exporting to the United States. As a result, the region would face a lower effective carbon import tariff because the firms with the highest emissions would have selected out of exporting, but the aggregate emissions intensity of the region would not have changed. Because the model uses only the aggregate emissions intensity estimated for each region, it would fail to capture that selection effect. Such trade reshuffling could lead to smaller reductions in global CO_2 emissions than projected in our analysis because regions could achieve a lower effective carbon import tariff rate without having to reduce their aggregate emissions by the same magnitude.

A second source of uncertainty is also related to the use of representative firms in CBO-EPPA. In the real world, there is variation in emissions intensity among firms within the same industry and within the same country.[22] A domestic emissions pricing policy might target only those firms with CO_2 emissions above a certain threshold, which would require knowing the distribution of emissions intensities among firms in each industry. Such a policy would apply to a limited number of firms and might prompt only the most emissions-intensive to reduce their CO_2 emissions. Likewise, if a similar policy was applied to imports, only the most emissions-intensive firms abroad would face increased costs. Those effects could encourage trade reshuffling, as firms with lower-than-average CO_2 emissions would not be subject to the carbon import tariffs. In that case, the tariffs' effect on foreign CO_2 emissions would be smaller than it is in our results.

Third, there is uncertainty about how the United States might design and adopt policies to reduce CO_2 emissions. In this analysis, we used the representative policy of a carbon tax, but actual policies could differ substantially. For instance, policies could include subsidies to incentivize the adoption of technologies or energy sources that produce lower emissions. Those subsidies could reduce energy prices and have different effects on output, trade, CO_2 emissions, or carbon leakage than those described in this paper. Alternatively, trade policies such as carbon import tariffs could be implemented without any accompanying domestic measures (such as a carbon tax). In that case, importers and exporters would face different tax rates than they do in the scenarios analyzed in this paper. Such policies would have different implications for output and trade flows. Additionally, state and local governments could impose their own policies to reduce emissions. Such regulations could increase costs for emissions-intensive firms, thereby encouraging greater reductions in CO_2 emissions.

Fourth, there is uncertainty about how technology will develop in the future. In CBO-EPPA, a path of exogenous technology growth is estimated using historical data and projections. However, actual growth could be faster or slower than projected, and the introduction of low-emissions technologies that are perfect substitutes for conventional energy carriers could change how emissions evolve. For example, growth in wind and solar technology might outpace projections and, as a result, emissions could fall faster than expected. If certain technologies made abatement more affordable in the future, the effects of a carbon tax on firms' competitiveness would be smaller.

Finally, there is uncertainty about how the policies analyzed in this paper might interact with other policies related to energy or trade. In the United States, energy policies have focused on providing subsidies to reduce or remove emissions. For example, certain tax credits provide subsidies for generating electricity using non-emitting sources such as wind and solar and for capturing CO_2 during the production process. If a carbon tax was enacted alongside subsidies for

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[22] Wayne B. Gray and Gilbert E. Metcalf, "Carbon Tax Competitiveness Concerns: Assessing a Best Practices Carbon Credit," *National Tax Journal*, vol. 70, no. 2 (June 2017), https://doi.org/10.17310/ntj.2017.2.08.

CO_2 reduction, those subsidies would lower the cost of CO_2 reduction. As a result, domestic firms would lose less competitiveness in relation to foreign firms, and carbon import tariffs and export rebates would be even more effective at increasing the competitiveness of domestic firms. Trade policies such as tariffs, however, would likely have the opposite effect on imports. If other tariffs were already in place, then the addition of carbon import tariffs would be less effective at reducing imports further.

WTO Compliance

Trading partners could view U.S. carbon import tariffs or export rebates as inconsistent with World Trade Organization rules and challenge those policies. The outcome of such challenges would depend on the specific design of the carbon import tariffs, export rebates, and carbon pricing policies.[23] The legality of carbon import tariffs and export rebates under WTO law is uncertain because no rules directly address those policies and no challenges to such policies have been adjudicated to date. Legal experts have analyzed WTO case law to speculate about how the organization might respond to such challenges.[24] A carbon import tariff or export rebate could be treated as a border tax adjustment under WTO law, but it would have to comply with the requirements of the General Agreement on Tariffs and Trade (GATT).

One key issue for GATT compliance is the principle of nondiscrimination, particularly the principles of most-favored-nation treatment and national treatment. Under GATT Article I, WTO members must treat imports from all trading partners equally, without assigning different tariff rates to similar goods from different countries. Article III requires that imports be treated the same as domestic goods. A carbon import tariff or export rebate could be challenged under one of those articles.

A potential defense for carbon import tariffs or export rebates is their classification as border tax adjustments, which are permitted under GATT Article II. Whether that classification applies depends on whether the underlying price on CO_2 emissions is considered an indirect tax—that is, a tax levied on goods or services rather than on income or profits. Since carbon content is not a tangible good, categorizing a price on CO_2 emissions as an indirect tax could be challenged. However, some legal experts have argued that any tax not classified as a direct tax (that is, not

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[23] Stéphanie Monjon and Philippe Quirion, "A Border Adjustment for the EU ETS: Reconciling WTO Rules and Capacity to Tackle Carbon Leakage," *Climate Policy*, vol. 11, no. 5 (2011), pp. 1212–1225, https://doi.org/10.1080/14693062.2011.601907.

[24] Javier de Cendra, "Can Emissions Trading Schemes Be Coupled With Border Tax Adjustments? An Analysis Vis-à-Vis WTO Law," *Review of European Community and International Environmental Law*, vol. 15, no. 2 (July 2006), pp. 131–145, https://doi.org/10.1111/j.1467-9388.2006.00518.x.

levied on production factors) could be considered an indirect tax, in which case a carbon import tariff or export rebate could qualify as a border tax adjustment under WTO law.[25]

If a carbon import tariff did not qualify as a border tax adjustment, it could be defended under GATT Article XX, which allows exceptions for measures necessary to protect human, animal, or plant life or health and for measures related to the conservation of exhaustible natural resources. Some experts have argued that the latter exception would be easier to justify. WTO case law has recognized air quality as an exhaustible resource that can be protected under trade law.[26] However, for that defense to be used, the measure in question must also satisfy the conditions in the GATT's chapeau, which require that the measure not be applied in an arbitrary or discriminatory manner or as a disguised restriction on international trade. A carbon import tariff designed to reduce carbon leakage and mitigate climate change would likely meet that requirement. However, if the policy consisted solely of a carbon import tariff without an accompanying domestic emissions pricing policy, it could be harder to defend.

A carbon export rebate could be defended under the same border tax adjustment provisions. If such a defense failed, the export rebate could be evaluated separately from the carbon import tariff under the Agreement on Subsidies and Countervailing Measures. In that case, the environmental protection defenses available under the GATT would not apply.

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[25] Aaron Cosbey and others, "Developing Guidance for Implementing Border Carbon Adjustments: Lessons, Cautions, and Research Needs From the Literature," *Review of Environmental Economics and Policy*, vol. 13, no. 1 (Winter 2019), pp. 9–10, https://doi.org/10.1093/reep/rey020.

[26] Henrik Horn and Petros C. Mavroidis, "To B(TA) or Not to B(TA)? On the Legality and Desirability of Border Tax Adjustments From a Trade Perspective," *World Economy*, vol. 34, no. 11 (November 2011), pp. 1911–1937, https://doi.org/10.1111/j.1467-9701.2011.01423.x.

Appendix A: Calibration of the CBO-EPPA Model

The Massachusetts Institute of Technology's Economic Projection and Policy Analysis model (MIT-EPPA) is an open-source, computable general equilibrium model of the world economy that projects economic and emissions outcomes over several decades. We modified a version of that model, MIT-EPPA7, to create CBO-EPPA, which incorporates the Congressional Budget Office's own projections of domestic and international economic growth and primary energy use, the domestic population, and carbon dioxide emissions. That information was used to calculate CBO-EPPA's base case for the 2030–2050 period. The base case is benchmarked to CBO's *2023 Long-Term Budget Outlook* and to the Energy Information Administration's (EIA's) *Annual Energy Outlook 2023* reference case, which reflects federal energy policies in place as of November 2022. Those projections were the most recent, internally consistent set of economic and energy projections available when the analysis was conducted, ensuring a coherent and integrated base case across the key drivers of emissions. Our modifications provide a more recent representation of the domestic and international outlook for the economy, energy use, and emissions than MIT-EPPA7's original base case. The three calibration steps and the data sources used to make those modifications are described below.

GDP and Population Calibration

We modified EPPA to align it with CBO's projections of gross domestic product (GDP) and population growth. GDP growth was calibrated by adjusting the model's total factor productivity parameter by region. For the United States (which is defined as its own region in EPPA), total factor productivity was adjusted until CBO-EPPA's projected growth of real GDP matched the growth projected in CBO's *2023 Long-Term Budget Outlook*.[1] The projections of U.S. population growth, an important determinant of EPPA's employment estimates, were also calibrated to match the projections in the *2023 Long-Term Budget Outlook*. In those projections, from 2023 to 2053, real GDP grows by an average of 1.6 percent per year, and the population by an average of 0.35 percent per year.[2]

For non-U.S. regions, total factor productivity was adjusted so that projected real GDP growth in CBO-EPPA matched the regional growth rates in the Organisation for Economic Co-operation and Development's long-term forecast of real GDP.[3]

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[1] Congressional Budget Office, *The 2023 Long-Term Budget Outlook* (June 2023), www.cbo.gov/publication/59014.

[2] The average GDP growth rate was calculated using a geometric mean.

[3] Organisation for Economic Co-operation and Development, *OECD Economic Outlook*, vol. 2020, no. 1 (June 2020), https://doi.org/10.1787/0d1d1e2e-en.

Energy Calibration

In the model, we imposed taxes or subsidies on energy use in the United States and in non-U.S. regions so that energy consumption in CBO-EPPA matched the consumption in EIA's *Annual Energy Outlook 2023 and International Energy Outlook 2023* reference cases.[4] In those projections, U.S. coal consumption declines from 5 exajoules (EJ) in 2030 to 3 EJ in 2050, while the use of natural gas and liquid fuels remains relatively constant, averaging 32 EJ and 38 EJ over the period, respectively. In terms of global patterns, the United States and China are projected to be the largest consumers of petroleum liquid fuels, the United States to lead in natural gas use, and China and India to be the largest consumers of coal.

The calibration steps above allowed us to account for policies imposed on energy markets that would otherwise be difficult to incorporate directly. Modeling individual tax provisions in CBO-EPPA is not practical because the model lacks a sufficiently granular representation of the economy to capture such policies. Instead, we calibrated the model to an energy-use pathway and inferred the taxes and subsidies required to generate those levels of energy use. For example, before the energy calibration, coal use in EPPA was higher than in CBO's projections, so we applied taxes to coal use and subsidies for natural gas, solar, and wind to align the base case with CBO's projections. That allowed us to include a reasonable depiction of energy policies in the model's existing framework.

CO_2 Emissions Calibration

U.S. energy-related CO_2 emissions were calibrated to align with an extended version of CBO's benchmark projection of greenhouse gas emissions.[5] In EPPA, emissions are calculated using emissions coefficients that translate energy use into resulting emissions. Those emissions coefficients remain mostly constant over time, but subtle changes in fuels (such as different types of coal or different mixtures of refined petroleum) can lead to slight differences in the emissions that those fuels produce. We adjusted the model's emissions coefficients so that the relationship between energy use and emissions aligned with CBO's projections of those variables. The analysis that informed those changes was based on historical data from the Environmental Protection Agency's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021* as well as projections of emissions from EIA's *Annual Energy Outlook 2023*.[6]

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[4] Energy Information Administration, *Annual Energy Outlook 2023* (March 2023), www.eia.gov/outlooks/archive/aeo23, and *International Energy Outlook 2023* (October 2023), www.eia.gov/outlooks/ieo.

[5] CBO's most recent benchmark projection covers the period from 2025 to 2034. See Congressional Budget Office, *CBO's Benchmark Projection of Greenhouse Gas Emissions* (December 2024), www.cbo.gov/publication/60862.

[6] Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021* (April 2023), https://tinyurl.com/k4zxanxv.

Appendix B: Sensitivity Analyses

We conducted sensitivity analyses to assess how much the effects of carbon import tariffs and export rebates would change if we adjusted the regions and sectors covered by those policies. In this appendix, we provide the results of those analyses and compare them with the main results.

Regional Coverage

In this sensitivity analysis, we assessed how results might differ if a region of the world was exempted from U.S. carbon import tariffs and export rebates. The illustrative policies in the main analysis were applied uniformly across all regions, but real-world policies could include exemptions for certain trading partners that have emissions-reduction policies of their own.

One potential region that could be exempted is the European Union, which operates the European Union Emissions Trading System (EU ETS), a cap-and-trade program in which firms buy and sell CO_2 permits. The EU ETS covers greenhouse gas emissions primarily from large stationary sources. Sectors included under the EU ETS are power generation, energy-intensive manufacturing, nonmetallic minerals, primary metals, oil refineries, and aviation. Unlike a carbon tax, the EU ETS sets a cap on the quantity of CO_2 emissions and allows the price per metric ton to fluctuate with market conditions. Between 2020 and 2025, EU ETS carbon prices ranged from about $60 to $80 per metric ton of CO_2, following a period of volatility during the COVID-19 pandemic.[7] Because those carbon prices exceed the tax of $25 per metric ton of CO_2 analyzed in this paper, policymakers could choose to exempt the European Union from carbon import tariffs and export rebates. To examine the effects of such an EU exemption, we analyzed scenarios in which the European Union was excluded from those policies.

In those scenarios, global emissions in most years are largely unchanged from the main results, resulting in no change in observed leakage rates over the 2030–2050 period. That is because the European Union is already a low-emissions trading partner and thus, in the main analysis, is subject to smaller carbon import tariffs and export rebates than other regions.

Some modest variation is observed in certain years, such as 2045 (see Table B-1). In that year, in the carbon import tariff case (with the European Union exempted), CO_2 emissions in the United States are lower by 27 million metric tons (MMT), while emissions outside the United States are higher by 3 MMT, resulting in a net reduction of 24 MMT. The carbon import tariff and export rebate case follows a similar overall pattern but with slightly larger magnitudes. In 2045, CO_2 emissions in the United States are 35 MMT lower than in the main results; that reduction is

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[7] International Carbon Action Partnership, "Allowance Price Explorer" (accessed February 19, 2026), https://icapcarbonaction.com/en/ets-prices.

slightly offset by a 4 MMT increase in emissions outside the United States, resulting in a net reduction of 31 MMT. However, those deviations each represent less than 0.1 percent of domestic and global emissions, respectively, and fall within the range of expected variation in a general equilibrium model of this scale. Thus, those variations do not alter the broader conclusion that observed leakage rates remain stable when the European Union is exempted from carbon import tariffs and export rebates.

Sectoral Coverage

In this sensitivity analysis, we examined how the simulation results change when additional sectors are covered. In the main analysis, carbon import tariffs and export rebates were applied to four sectors: energy-intensive manufacturing, nonmetallic minerals, petroleum and coal products, and primary metals. To explore the effects of expanding sectoral coverage, we ran a simulation that included two additional sectors: agriculture (crops, forestry, and livestock) and mining (coal, crude oil, natural gas, and other mining activities). Both of those sectors release emissions and are exposed to international trade. Agriculture relies on energy for on-site equipment, irrigation, and structures, whereas mining is integrated into energy systems, particularly fossil fuel extraction.

Adding the agriculture and mining sectors to the simulation has little impact on U.S. and global CO_2 emissions (see Table B-2). Over the 2030–2050 period, the change in total U.S. CO_2 emissions in the carbon import tariff case fluctuates between −0.3 percent and 0.8 percent; in the carbon import tariff and export rebate case, the change ranges from −0.3 percent to 0.2 percent. CO_2 emissions outside the United States increase in the carbon import tariff and export rebate case, as U.S. sectors involved in fossil fuel extraction receive carbon export rebates. That leads to greater availability of fossil fuels in the global energy system, resulting in a modest rise in global CO_2 emissions. However, the increase in non-U.S. CO_2 emissions over the period remains limited, ranging from 0.01 percent to 0.13 percent.

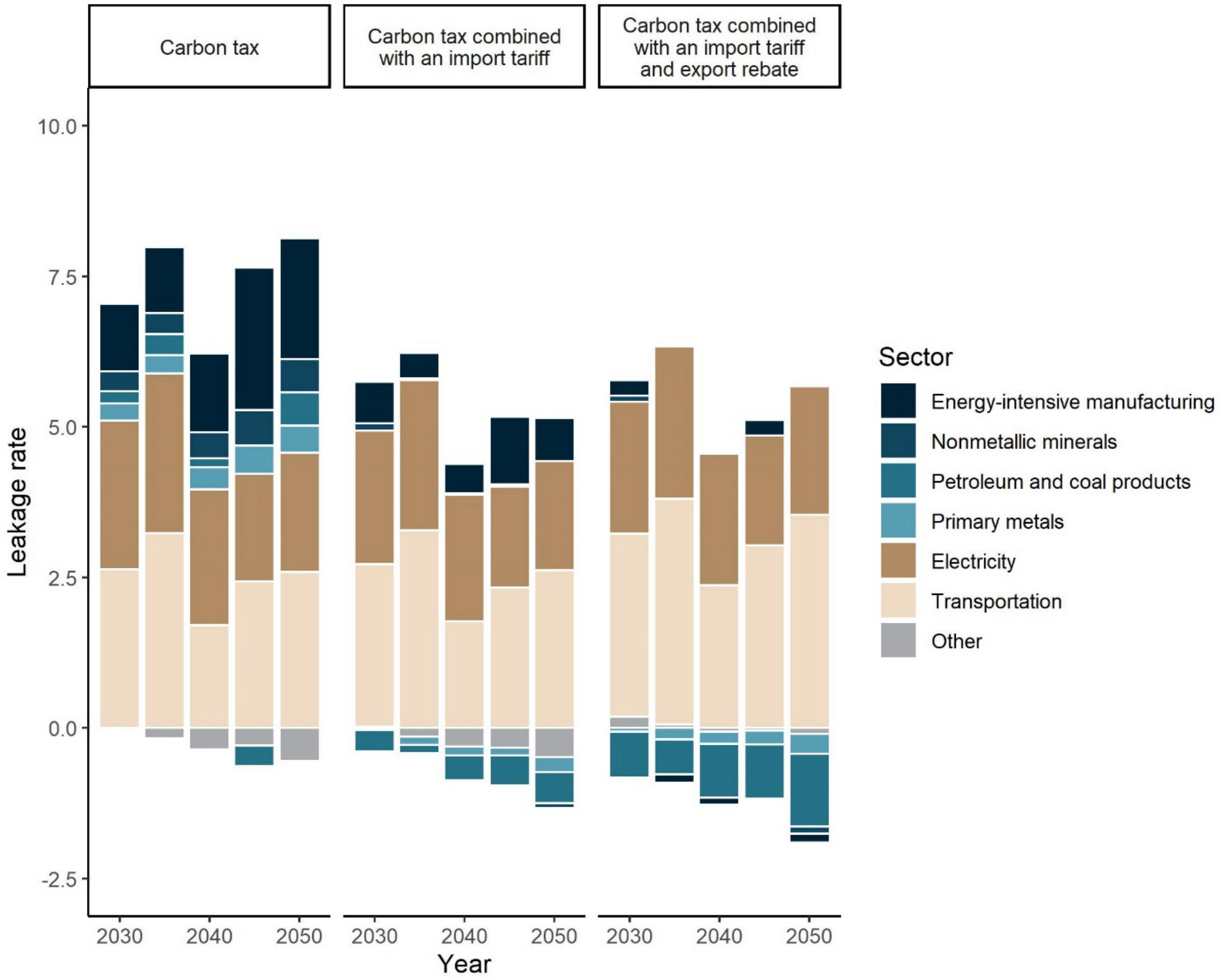
As a result, the overall change in global CO_2 emissions is small in relation to changes in the main set of cases. In the carbon import tariff case, some production returns to the United States and production in non-U.S. regions is largely unchanged, so the leakage rate is about the same as in the main case. In the carbon import tariff and export rebate case, emissions outside the United States increase because export rebates lower the world market price of U.S. fossil fuels. That causes the leakage rate in 2050 to be 4 percentage points higher than it is in the main case.

Figures

Figure 1. [Return to Text]

Carbon Dioxide Leakage, by Sector

Percent



Data source: Congressional Budget Office.

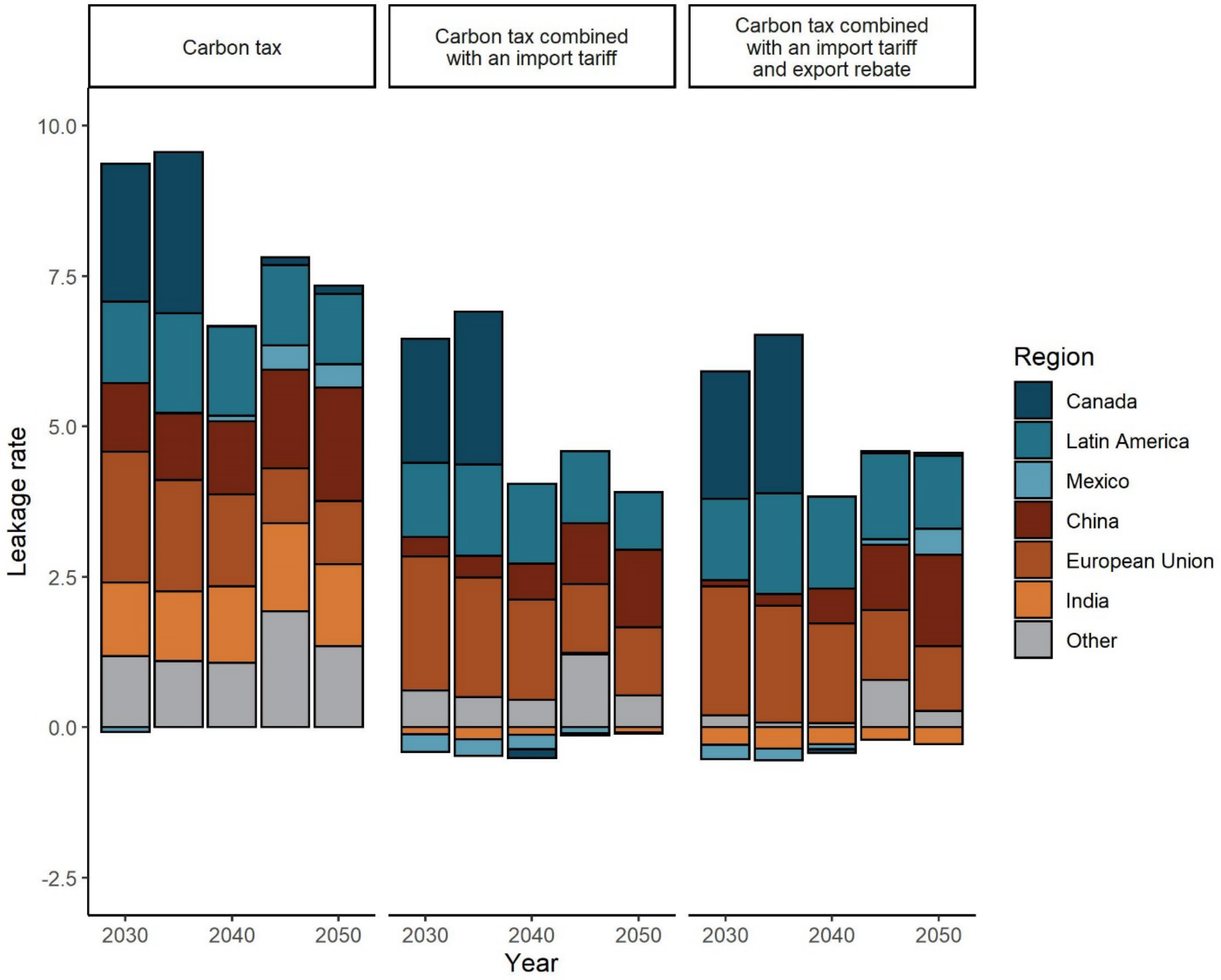
The first four sectors listed—energy-intensive manufacturing, nonmetallic minerals, petroleum and coal products, and primary metals—are commonly traded and more exposed to international markets. The two following sectors—electricity and transportation—are less traded and therefore more likely to exhibit leakage resulting from lower global fuel prices than from changes in trade flows. Each of those six sectors uses more energy than the combined sectors in the “other” category.

Leakage is calculated as the ratio of the increase in non-U.S. CO_2 emissions to the reduction in U.S. CO_2 emissions.

Figure 2. [Return to Text]

Carbon Dioxide Leakage, by Region

Percent



Data source: Congressional Budget Office.

Leakage is calculated as the ratio of the increase in non-U.S. CO_2 emissions to the reduction in U.S. CO_2 emissions.

Tables

Table 1.

[Return to Text]

Regions and Sectors in the EPPA Model

Regions	Sectors
United States	Agriculture (crops)
Canada	Agriculture (forestry)
Mexico	Agriculture (livestock)
Japan	Coal
Australia, New Zealand, and Oceania	Crude oil
European Union	Electricity
Eastern Europe and Central Asia	Energy-intensive manufacturing
Russia	Food products
East Asia	Natural gas
South Korea	Nonmetallic minerals
Indonesia	Ownership of dwellings
China	Petroleum and coal products
India	Primary metals
Brazil	Services
Africa	Transport
Middle East	Other industries
Latin America	
Rest of Asia	

Data source: Yen-Heng Henry Chen and others, “A Multisectoral Dynamic Model for Energy, Economic, and Climate Scenario Analysis,” *Low Carbon Economy*, vol. 13, no. 2 (June 2022), https://doi.org/10.4236/lce.2022.132005.

The electricity sector includes transmission and distribution of electricity from eight sources: coal, natural gas, hydroelectric, nuclear, oil, solar, wind, and other energy sources. CO_2 emissions from those sectors are counted as CO_2 emissions from the electricity sector.

EPPA = Economic Projection and Policy Analysis.

Table 2. [Return to Text]

Changes in the Output of U.S. EITE Sectors in the Three Illustrative Policy Cases, 2030 to 2050

Percent

Case	Sector	2030	2035	2040	2045	2050	Average, 2030–2050
Carbon tax	Energy-intensive manufacturing	-1.2	-1.2	-1.3	-1.8	-1.5	-1.4
	Primary metals	-1.3	-1.2	-1.3	-1.8	-1.5	-1.4
	Nonmetallic minerals	-1.2	-1.3	-1.4	-1.9	-1.8	-1.5
	Petroleum and coal products	-5.7	-6.1	-7.5	-11.9	-9.5	-8.2
	Total EITE	-2.0	-2.0	-2.2	-3.2	-2.6	-2.4
Carbon tax combined with an import tariff	Energy-intensive manufacturing	-0.9	-0.7	-0.7	-0.8	-0.6	-0.7
	Primary metals	-0.1	0.4	0.7	0.9	1.4	0.6
	Nonmetallic minerals	-0.5	-0.3	-0.2	-0.2	0.1	-0.2
	Petroleum and coal products	-6.2	-5.9	-7.3	-9.2	-9.4	-7.6
	Total EITE	-1.7	-1.4	-1.5	-1.8	-1.6	-1.6
Carbon tax combined with an import tariff and an export rebate	Energy-intensive manufacturing	-0.1	0.3	0.5	0.8	1.3	0.6
	Primary metals	0.6	1.4	1.9	2.4	3.3	1.9
	Nonmetallic minerals	-0.1	0.2	0.4	0.6	1.0	0.4
	Petroleum and coal products	-5.7	-5.2	-6.3	-7.3	-8.0	-6.5
	Total EITE	-1.0	-0.5	-0.4	-0.2	0.2	-0.4

Data source: Congressional Budget Office.

All values are expressed as a percentage change from the base case. The last column shows the simple average of the observations for each five-year period from 2030 to 2050.

EITE = energy-intensive and trade-exposed.

Table 3. [Return to Text]

Changes in U.S. EITE Product Imports and Sector Exports in the Three Illustrative Policy Cases, 2030 to 2050

Percent

Case	Sector	2030	2035	2040	2045	2050	Average, 2030–2050
Carbon tax	Imports	-0.1	0.1	0.1	-0.1	0.2	0.1
	Exports	-1.6	-1.6	-1.8	-2.4	-2.2	-1.9
Carbon tax combined with an import tariff	Imports	-1.2	-1.3	-1.4	-1.7	-1.9	-1.5
	Exports	-2.4	-2.5	-2.8	-3.3	-3.7	-3.0
Carbon tax combined with an import tariff and an export rebate	Imports	-1.4	-1.6	-1.8	-2.1	-2.4	-1.9
	Exports	1.4	2.3	2.9	3.6	4.8	3.0

Data source: Congressional Budget Office.

All values are expressed as a percentage change from the base case. The last column shows the simple average of the observations for each five-year period from 2030 to 2050.

EITE = energy-intensive and trade-exposed.

Table 4.

[Return to Text]

Changes in Carbon Dioxide Emissions and Carbon Leakage Rates, 2030 to 2050

Millions of metric tons of CO_2

Case	Sector	2030	2035	2040	2045	2050	Average, 2030–2050
Carbon tax	U.S. CO_2 emissions	-477	-582	-704	-946	-1,014	-745
	U.S. EITE CO_2 emissions	-65	-106	-159	-206	-238	-155
	Non-U.S. CO_2 emissions	44	56	47	74	74	59
	Leakage (percent)	9	10	7	8	7	8
Carbon tax combined with an import tariff	U.S. CO_2 emissions	-495	-581	-703	-868	-1,025	-734
	U.S. EITE CO_2 emissions	-64	-103	-155	-194	-235	-150
	Non-U.S. CO_2 emissions	30	37	25	39	39	34
	Leakage (percent)	6	6	4	4	4	5
Carbon tax combined with an import tariff and an export rebate	U.S. CO_2 emissions	-494	-575	-697	-837	-1,020	-725
	U.S. EITE CO_2 emissions	-59	-97	-147	-183	-223	-142
	Non-U.S. CO_2 emissions	27	34	24	37	44	33
	Leakage (percent)	5	6	3	4	4	4
Addendum:							
Base case (total amounts)	U.S. CO_2 emissions	4,199	4,135	4,135	4,183	4,245	4,179
	U.S. EITE CO_2 emissions	912	927	947	948	982	943
	Non-U.S. CO_2 emissions	29,089	29,983	30,587	31,400	32,485	30,709

Data source: Congressional Budget Office.

CO_2 emissions in the carbon tax, carbon import tariff, and carbon import tariff and export rebate cases are shown as relative changes from the base case. The leakage rate is the ratio of the increase in non-U.S. CO_2 emissions to the reduction in U.S. CO_2 emissions.

EITE = energy-intensive and trade-exposed.

Table B-1. [Return to Text]

Sensitivity Analysis of EU Exemptions From Trade Policies: Changes in Carbon Dioxide Emissions and Carbon Leakage Rates, 2030 to 2050

Millions of metric tons of CO_2

Case	Sector	2030	2035	2040	2045	2050	Average, 2030–2050
Carbon tax combined with an import tariff	U.S. CO_2 emissions	4	0	1	-27	4	-4
	Non-U.S. CO_2 emissions	0	0	0	3	1	1
	Global CO_2 emissions	4	1	1	-24	4	-3
	Leakage (percentage points)	0	0	0	0	0	0
Carbon tax combined with an import tariff and an export rebate	U.S. CO_2 emissions	3	-1	-1	-35	2	-6
	Non-U.S. CO_2 emissions	1	1	1	4	-1	1
	Global CO_2 emissions	4	0	0	-31	2	-5
	Leakage (percentage points)	0	0	0	0	0	0

Data source: Congressional Budget Office.

All values are expressed as changes from the main results shown in Table 4.

Table B-2. [Return to Text]

Sensitivity Analysis Including the Agriculture and Mining Sectors: Changes in Carbon Dioxide Emissions and Carbon Leakage Rates, 2030 to 2050

Millions of metric tons of CO_2

Case	Sector	2030	2035	2040	2045	2050	Average, 2030–2050
Carbon tax combined with an import tariff	U.S. CO_2 emissions	-14	-4	-4	33	-12	0
	Non-U.S. CO_2 emissions	0	2	1	-4	1	0
	Global CO_2 emissions	-14	-2	-3	29	-11	0
	Leakage (percentage points)	0	0	0	0	0	0
Carbon tax combined with an import tariff and an export rebate	U.S. CO_2 emissions	-13	-3	-2	10	-8	-3
	Non-U.S. CO_2 emissions	8	14	18	25	41	21
	Global CO_2 emissions	-5	10	15	35	33	18
	Leakage (percentage points)	1	2	3	3	4	3

Data source: Congressional Budget Office.

All values are expressed as changes from the main results shown in Table 4.