Energy Market and Trade Implications of Carbon Border Adjustments for the US Manufacturing Sector

Charalampos Avraam[*,∓], Maxwell Brown[†], Kristina Pitman[*,†], Daniel Steinberg[*]

[*] US Department of Energy National Renewable Energy Laboratory
[†] Colorado School of Mines, Division of Economics and Business
[∓] Corresponding Author: Charalampos.Avraam@nrel.gov

October 16, 2024

Abstract

Manufacturing decarbonization strategies aim to accelerate the deployment of carbon-free energy supply and the associated manufactured products, and typically focus on the top three emitting industries globally: steel, cement, and chemicals. The high energy intensity of manufacturing processes implies that there does not exist a single dominant decarbonization strategy for the US manufacturing sector. In addition, the 32% import share in 2023 exposes the US manufacturing sector to strong international competition. This effect is intensified if the externalities of embodied carbon emissions of imported goods are not properly priced. Carbon Border Adjustments (CBAs) are policy instruments that aim to price the emissions-related externalities of imports via a fee based on their carbon footprint. Understanding whether CBAs can align incentives for international competitors given domestic decarbonization policies remains a challenge. In this study, we reveal the impact of international trade on decarbonization policies for the US steel, cement, and ammonia sectors. In highly decarbonized futures, we demonstrate the impact of CBAs on technological deployment in the energy and manufacturing sectors in the US. Finally, we reveal trade-offs between downstream policies and upstream deployment of biofuel pathways. This work expands the capabilities of the Fuels and INdustry InTegrated Optimization (FINITO) model, a state-of-the-art, energy system-wide model, with a bottom-up technology-rich representation of the US steel, cement, ammonia, and clean fuels (biofuels, hydrogen, and e-fuels) sectors.

Motivation

The exposure of the US manufacturing sector to international competition has the potential to substantially reduce the efficacy of domestic decarbonization policies due to production leakage driven by such policies. The import share of the US manufacturing sector in 2023 was 32%. In addition, the manufacturing sector includes energy-intensive, high-pressure and high-temperature processes which are hard to abate [USDOE, 2024]. Less stringent Greenhouse Gas (GHG) emissions regulation in exporting countries can render imported commodities more competitive, and lead to increased imports of commodities with higher embodied carbon emissions and suboptimal levels of global GHG emissions.

Broadly, the manufacturing sector ranks second in energy consumption, comprises hard-to-abate industries, and interacts with multiple energy suppliers [USDOE, 2024]. Specifically, the manufacturing sector consumed 23% of the total end-use energy in 2023 [EIA, 2023]. Depending on the technologies used within a facility, manufacturing processes can require any combination of electricity, hydrogen, fossil fuel, and biofuel inputs. The hard-to-abate manufacturing industries include iron, steel, and cement, which, combined with chemicals, accounted for 70% of global industrial emissions in 2021 [IEA, 2022]. The more than $12 billion in the Bipartisan Infrastructure Law to Carbon Capture, Utilization, and Storage (CCUS) incentives [USDOE, 2024] signal that emissions reduction in the manufacturing sector also occurs through the deployment of CCUS technologies. Therefore, the sectoral interdependencies of the manufacturing sector extend beyond the electricity, hydrogen, fuels and biofuels infrastructures and include also the carbon capture, transportation, and storage infrastructure.

A Carbon Border Adjustment (CBA) is a policy instrument that aims to price the emissions-related externalities of imported commodities via a fee based on their carbon footprint, and can be designed to complement existing emissions reduction regulation [Kopp et al., 2023]. The European Union (EU) rolled out its own Carbon Border Adjustment Mechanism (CBAM) in 2023 [EU, 2023]. The Fair, Affordable, Innovative, and Resilient Transition and Competition Act (FAIR Act) [Walberg, 2023] and the Clean Competition Act (CCA) [Whitehouse, 2023] were submitted to the US House of Representatives and Senate respectively in the same year. Despite recent legislation, understanding whether CBAs can align incentives for international competitors given domestic decarbonization policies remains a challenge. First, the lack of a single dominant decarbonization strategy for the US manufacturing sector complicates policy design. The design of cross-sectoral decarbonization policies requires a deeper understanding of the inter-dependencies between the manufacturing sector, international trade, energy, and CCUS infrastructures. Second, data on existing and prospective manufacturing processes are scarce, preventing analysis efforts.

Therefore, in this study we ask the following.

- What is the interplay between international policy design and domestic decarbonization policy design for the interdependent energy and manufacturing sectors?
- How does the design of CBAs affect the regional deployment of clean energy and manufacturing technologies in the US under highly decarbonized futures?
- What are the welfare implications of combinations of CBAs and decarbonization strategies on domestic manufacturing producers and international consumers?

Methods

This study leverages the Fuels and INdustry InTegrated Optimization (FINITO) model, a spatially explicit model of the US energy system with a bottom-up, technology-rich representation of the industrial and fuel supply sectors. FINITO is formulated as a linear program and simulates the least-cost evolution and operation of the US industrial manufacturing and fuel-supply sectors in order to meet projected demands for industrial commodities, including steel, cement, and ammonia, and demands for energy in the industrial, transportation, and buildings sectors. Existing industrial and fuel-production facilities, primary energy resources, policies, demand for commodities, and demand for fuels, among other key inputs are characterized over 134 sub-state regions, within and between which the model explicitly captures the production, capture (in the case of CO_2), transport, storage, and use of industrial commodities, energy carriers, and emissions.

FINITO comprises a comprehensive database of industry-, state-, and commodity-specific policies, including rate-based policies, carbon taxes and carbon caps. Currently, FINITO represents a range of incentives in the Inflation Reduction Act (IRA), including the Clean Fuel Production Tax Credit (45Z), the IRA Clean Hydrogen (45V) incentive, the IRA Carbon Oxide Sequestration (45Q) incentive, and Renewable Fuel Standards requirements.

The proposed analysis in the following section is largely based on the built-in capabilities of FINITO, which tracks regional production and investment decisions, the levelized cost of industrial, hydrogen, and biofuel facilities (including variable and fixed operations and maintenance costs, capital expenditures, cost of mineral inputs for steel facilities, energy costs), and sub state-level embodied carbon emissions and carbon capture and storage.

Scope and Proposed Analysis

We focus on the implications of CBAs for the US energy and manufacturing sectors and the interplay between international trade and decarbonization policies. Our work contributes to understanding the implications of proposed legislative efforts in the US, including the FAIR Act [Walberg, 2023] and the CCA [Whitehouse, 2023] in 2023. Moreover, this study contributes to international trade policy design via the evaluation of a variety of decarbonization policies *in tandem* with CBAs, and the comparison of the results with target outcomes of the newly implemented CBAM by the European Union in 2023 [EU, 2023].

In this study, we enhance FINITO to account for international trade of steel, cement, and ammonia and explore different implementations of the CBA for the US, leading to a range of fees. For each fee level, we explore multiple decarbonization policies, targeting different points in the US energy and manufacturing supply chains. The scenario analysis reveals three key trade-offs. The first is the interplay between international policy design and domestic decarbonization policy design for the inter-dependent energy and manufacturing sectors. The second is the impact of CBAs on the deployment of biofuels and hydrogen technologies in the US energy sector, and cleaner processes in the manufacturing sector at the sub-state level under highly decarbonized futures. The third includes the trade-offs between operational and investment costs, emissions, import share and social welfare impacts on domestic producers and international consumers in the manufacturing sectors.

References

EIA. Annual Energy Outlook: Total Energy, 2023. Data retrieved from the US Energy Information Administration, https://www.eia.gov/totalenergy/data/annual/. For the calculation of the percentage energy consumption of each sector in 2023, we divide the annual consumption of energy from the transportation (in Table 2.1.a) and manufacturing (in Table 2.1.b) sectors by the total annual energy consumption in 2023 (in Table 2.1.a).

EU. *Carbon Border Adjustment Mechanism*. European Union, 2023. URL https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en.

IEA. *Achieving Net Zero Heavy Industry Sectors in G7 Members*. Executive Summary, International Energy Agency, OECD Publishing, 2022. URL https://www.iea.org/reports/achieving-net-zero-heavy-industry-sectors-in-g7-members/executive-summary.

Raymond Kopp, William Pizer, and Kevin Rennert. Carbon border adjustments: Design elements, options, and policy decisions. *Resources for the Future*, 2023. URL https://media.rff.org/documents/Report_23-14.pdf.

USDOE. Scaling Carbon Capture for Hard-to-Abate Industries in the United States and Globally, 2024. URL https://www.energy.gov/fecm/articles/scaling-carbon-capture-hard-abate-industries-united-states-and-globally.

Tim Walberg. *FAIR Act of 2023*. 118th Congress of the United States of America (2023-2024), 2023. URL https://www.congress.gov/bill/118th-congress/house-bill/1525.

Sheldon Whitehouse. *Clean Competition Act*. 118th Congress of the United States of America (2023-2024), 2023. URL https://www.congress.gov/bill/118th-congress/senate-bill/3422.