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Environmental Ambition and Economic Protectionism: The Design of Border Carbon Adjustments

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Border carbon adjustments are becoming a central tool in climate-trade policy, but their environmental value depends on design. In the global steel industry, a mass-based border charge that prices total embodied emissions sends a much stronger carbon signal than a rate-based charge that prices emissions only above a benchmark. The benchmark acts like an output subsidy: it cushions downstream users, but it also encourages reshuffling, weakens incentives to abate abroad, and can shift emissions into underpriced upstream intermediates.

The Architecture of Border Carbon Adjustments

Unilateral climate policy asks governments to solve two problems at once. They want domestic carbon pricing to reduce emissions in energy-intensive and trade-exposed industries, but they also want to avoid simply moving production, jobs, and rents to countries with weaker climate policies. Border carbon adjustments (BCAs) are meant to help by charging imports for the emissions embodied in traded goods. Whether they can do that, however, depends less on the label "BCA" than on the architecture chosen.

The central design choice is whether the border measure prices total embodied emissions or only emissions above an intensity benchmark. A mass-based BCA, such as the logic behind the European Union Carbon Border Adjustment Mechanism, charges for the full emissions content of imports. A rate-based BCA, more common in recent US policy discussions, charges only the difference between an importer's emissions intensity and a benchmark. That distinction is not administrative fine print. It determines how much climate ambition is transmitted abroad, which firms receive protection, and where in the supply chain emissions can escape the policy.

The Hidden Subsidy in Benchmarked Designs

The economic problem with rate-based BCAs is that they are not pure carbon prices. Because the importer pays only for emissions above the benchmark, the benchmark effectively grants a credit on every unit of output. The policy therefore combines an emissions charge with an implicit output subsidy. It charges carbon, but it also rewards volume.

This subsidy weakens the signal reaching foreign producers. In the EU-style case studied in the paper, where the border measure extends a domestic carbon price, the rate-based design transmits only 36 percent of the mass-based border price needed to achieve the same global emissions reduction. Put differently, the benchmark acts like a 64 percent discount on the carbon price. In a US-style case without a domestic carbon-price anchor, the effective signal falls to about one-eighth of the corresponding mass-based benchmark. A government may announce a high nominal border fee, but the incentive actually reaching a foreign mill can be far smaller.

Why Steel Makes the Design Choice Visible

Steel is an especially useful setting for studying these incentives. It is responsible for roughly 7 percent of global greenhouse gas emissions, is heavily traded, and is central to current debates over climate policy and industrial competitiveness. It also combines two features that make border design matter: large differences in plant-level emissions intensity and a vertically linked supply chain.

The first feature is technological heterogeneity. Steel can be produced through integrated blast furnace-basic oxygen furnace plants, which rely on iron ore and coal and are highly emissions intensive, or through electric arc furnaces, which can rely more heavily on scrap and cleaner electricity. The mix of these technologies varies across products and regions. Flat steel used in autos and appliances relies more heavily on integrated production, while long steel used in construction is often produced in electric arc furnaces. When firms or regions operate both cleaner and dirtier capacity, a border measure can change where existing output is sent without necessarily changing total emissions.

This is the reshuffling problem. Under a benchmarked rate-based BCA, exporters can respond by sending cleaner electric-arc-furnace output to the regulated market and selling more carbon-intensive output elsewhere. The regulated market then appears cleaner, but global emissions fall much less. Mass-based BCAs are harder to arbitrage in this way because every ton of embodied emissions is priced, not just the gap between a plant's intensity and a benchmark.

Vertical Leakage Through Intermediates

The second feature is the vertical structure of steel. Carbon-intensive iron can be produced on site, embedded in finished steel, or traded separately as pig iron or direct reduced iron. This matters because a border policy that does not fully follow embodied emissions through the chain can leave upstream carbon underpriced.

The model shows how this creates vertical leakage. If downstream steelmakers face a domestic carbon cost but imported pig iron is weakly priced under a benchmark, they have an incentive to use more imported carbon-intensive intermediates. In the EU-style comparison, the rate-based design more than doubles pig iron imports relative to the

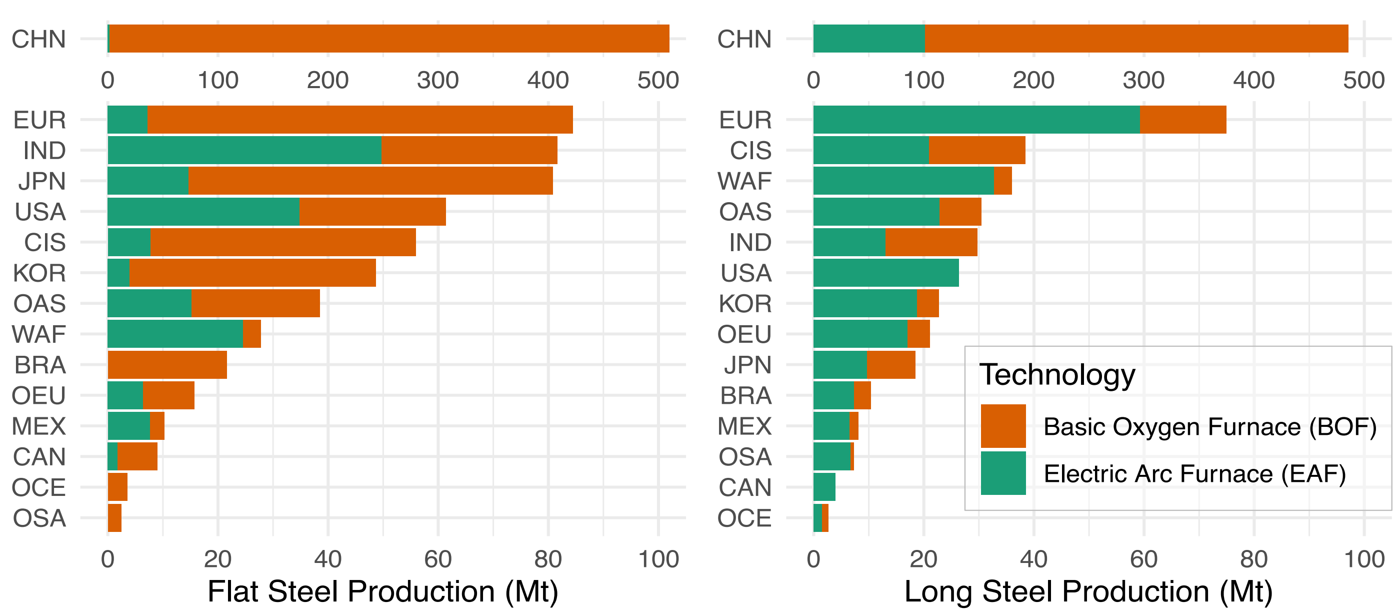

Figure 1. Comparison of steel production routes across key regions.

Notes: The figure distinguishes flat steel and long steel production by region and technology. Flat products rely more heavily on integrated blast furnace-basic oxygen furnace production, while long products are more often produced in scrap-based electric arc furnaces. This heterogeneity helps explain why exporters can reshuffle cleaner output toward regulated markets without reducing total emissions.

mass-based BCA and leaves the import price about 41 percent lower. That channel is easy to miss in aggregate sector models, but it is central in a vertically linked industry such as steel.

Efficiency, Incidence, and Leakage

The design choice also changes the cost of reaching a climate target. A mass-based BCA activates both the technology margin and the scale margin: producers have incentives to lower emissions intensity, and users face prices that reflect the carbon content of steel. Rate-based designs weaken the second channel because the benchmark subsidy cushions downstream users from part of the carbon cost. As a result, the policy relies more on changes in sourcing and production composition, which are more costly and more vulnerable to reshuffling.

The quantitative results show the size of the difference. At a stringency corresponding to a 30 percent reduction in EU domestic steel emissions, the mass-based BCA reduces global steel emissions by 1.34 percent. The rate-based design reduces global emissions by only 1.02 percent and raises EU welfare losses by about 55 percent relative to the mass-based design. Leakage also rises sharply, from 16 percent under the mass-based BCA to 36 percent under the rate-based BCA.

Despite their inefficiency, rate based designs may have political appeal. They protect downstream users, including construction, automotive, machinery, and other steel-intensive sectors, by limiting price increases. But that protection comes by weakening protection for domestic upstream producers and by forgoing fiscal revenue that a mass-based charge would collect. In other words, a benchmarked BCA is not just a softer climate instrument. It reallocates protection along the supply chain.

The Role of a Domestic Carbon-Price Anchor

The policy environment also matters. When a border measure complements an existing domestic carbon price, as in the EU-style case, the key question is how effectively the BCA extends that domestic signal to imports. When no domestic carbon price exists, as in the US-style case, the border measure has weaker climate leverage. In the simulations, the rate-based standalone instrument delivers only about one-quarter of the global emissions reduction achieved by a comparable mass-based charge. More broadly, without a domestic carbon-price anchor, the policy mainly shifts

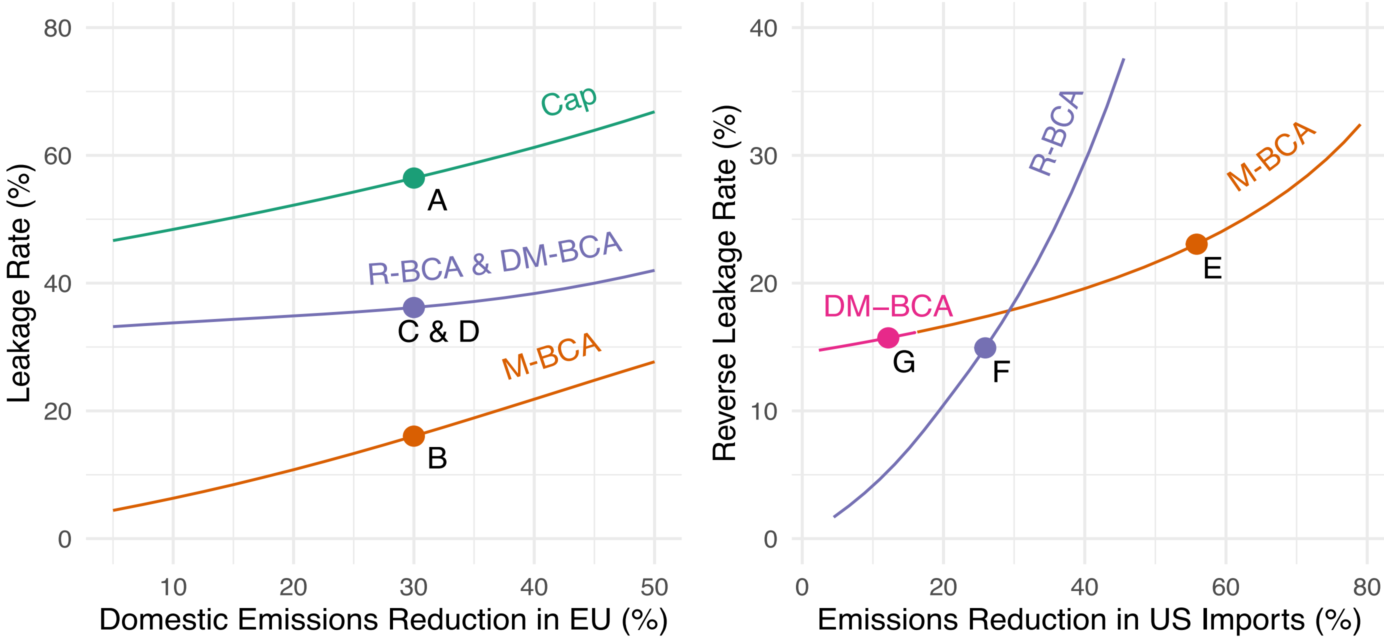

Figure 2. Standard leakage vs. reverse leakage under alternative BCA designs.

Notes: The figure compares a domestic-only carbon price ("Cap"), a mass-based BCA ("M-BCA"), a rate-based BCA ("R-BCA"), and a discounted mass-based comparison ("DM-BCA") that matches the global abatement of the rate-based design. The EU-style case shows the border measure extending domestic carbon pricing; the US-style case shows a standalone border instrument that can shift production onshore without generating comparable global abatement.

scarcity rents toward domestic downstream users rather than inducing substantial abatement abroad.

This point is important for current policy debates. BCAs can extend domestic climate ambition, but they are poor substitutes for it. A border charge that operates without a domestic price can protect domestic output and shift production patterns, but the environmental gains are limited unless producers and consumers also face a meaningful carbon signal at home.

Implications for Policy Design

The findings point to four design lessons. First, mass-based BCAs should be the default for homogeneous upstream materials and vertically linked supply chains, where benchmarked designs are especially vulnerable to arbitrage. Second, border measures are most credible when anchored in domestic carbon pricing. Third, regulators need to track embodied emissions across the full supply chain, including pig iron, direct reduced iron, and semi-finished steel, not only final products. Fourth, effective climate policy requires that at least part of the carbon cost reaches users and final consumers; if policymakers use benchmarks to cushion price increases, complementary charges or domestic carbon pricing can help restore the scale incentive and generate revenue for recycling.

The broader lesson is that BCA architecture determines whether a policy primarily transmits climate ambition abroad or primarily reallocates protection at home. In steel, mass-based designs preserve the carbon-price signal, limit reshuffling, and better capture emissions in traded intermediates. Rate-based designs can ease downstream price pressure, but they do so by weakening the environmental mechanism that makes a BCA useful in the first place.

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Link to the full working paper discussed in this brief:

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