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Border Carbon Adjustments When Carbon Intensity Varies across Producers: Evidence from California†

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Levels of climate ambition—and the stringency of climate policies—vary significantly across states and nations. When only a subset of firms are subject to costly greenhouse gas (GHG) emission regulations, industrial production and associated emissions may shift toward unregulated jurisdictions. The potential for emissions "leakage" poses a formidable challenge for jurisdictions hoping to reduce global GHG emissions using local or regional policies.

A government that imposes a tax on its own emissions (via a carbon tax or cap-and-trade program) can, in principle, mitigate emissions leakage by imposing a commensurate tax on the GHG emissions embodied in the products it imports.[1] Pricing carbon at the border can help level the carbon playing field for domestic and foreign suppliers.[2] This border carbon adjustment (BCA) concept is gaining momentum. The European Union has recently proposed a carbon price on imports of carbon-intensive goods for trading partners that do not implement commensurate climate policies.[3] In the United States, the Federal Energy Regulatory Commission has authorized BCAs on interstate electricity trade (Federal Energy Regulatory Commission 2020).

There is a rich literature in economics that analyzes how BCAs can work in theory. Here we begin to investigate how this concept is working in practice. In particular, we highlight the design challenges that arise when carbon intensity varies across sources. Since 2013, electricity imports into California have been taxed on the basis of GHG emissions intensity. Significant variation in the carbon intensity of out-of-state producers has complicated the implementation of this border adjustment. We simulate electricity market outcomes under BCA designs that differ in terms of how the carbon content of imports is assessed. A comparison of observed emissions outcomes against our simulation-based projections provides a means of assessing real-word impacts.

I. Calibrating Border Adjustments

The calibration of a carbon adjustment on imported goods involves nuanced trade-offs between firm-level abatement incentives, the integrity of GHG accounting, and legal pitfalls (Cosbey et al. 2019). The simplest approach taxes imports on the basis of a sector-specific average measure of emissions intensity, possibly differentiating by region of origin. This approach is relatively straightforward to implement but provides little incentive for an individual exporter to reduce emissions intensity. Moreover, a single benchmark applied uniformly to all imports will fail to reflect heterogeneity in firm-level emissions intensity, which can be significant (Lyubich, Shapiro, and Walker 2018). If the benchmark is set low, some imports will appear less carbon intensive than they are. This can result in emissions leakage. But if the benchmark is set high, this invites the challenge of unfair discrimination against low-carbon imports vis-à-vis comparable domestic producers.

Given concerns about trade protectionism, the legality of a BCA can be improved by

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[1] Whereas leakage concerns apply to any incomplete GHG regulation that imposes costs on regulated GHG emitters, more prescriptive approaches (such as performance standards) do not require an explicit payment per ton of GHG. This makes it much more difficult to establish a transparent basis for a border adjustment charge.

[2] Carbon adjustments can also be made to domestic exports competing with unregulated foreign production. This analysis will focus on imports exclusively.

[3] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12228-Carbon-Border-Adjustment-Mechanism.

allowing foreign producers to demonstrate that they outperform an industry-specific intensity benchmark. An advantage of this approach is that it creates an incentive for exporting firms to invest in reducing their emissions intensity. A disadvantage is that it creates incentives for resource "shuffling." If less carbon-intensive sources are preferentially allocated to supply the jurisdiction imposing the BCA, more carbon-intensive sources may backfill to meet demand in the unregulated jurisdiction. This shuffling of out-of-state resources means that the "deemed" emissions associated with imports will underestimate the true emissions impacts.

II. The California Case

California's Global Warming Solutions Act of 2006 (AB 32) set a goal of reducing statewide GHG emissions to 1990 levels by 2020. By 2018, California had surpassed this target. The power sector has been pivotal in this effort, delivering 75 percent of GHG reductions between 2006–2018. Notably, over half of California's GHG reductions since 2006 are attributed to reduced emissions from electricity imports (California Air Resources Board 2020).

When AB 32 was passed, almost 18 percent of California's electricity consumption—and more than half of the GHGs associated with this consumption—came from out-of-state imports. It was clear that a meaningful commitment to GHG emissions reductions should include electricity imports, but jurisdictional constraints limit California's ability to directly regulate emissions from out-of-state producers. To work around this constraint, California's GHG cap-and-trade program is designed to regulate not only in-state power producers but also electricity *importers*. All regulated sources are required to offset GHG emissions with compliance instruments (GHG permits or offsets).

To determine the compliance obligation of electricity imports, policymakers defined a "default" GHG emissions intensity (0.428 tonnes CO_2/MWh) based on the average intensity of underutilized out-of-state electricity producers in 2006–2008. Imposing this default factor on all imports would discriminate against low-carbon out-of-state resources. The California BCA regime allows electricity importers to demonstrate that their out-of-state sources have a lower carbon intensity, provided that they meet the requirements for "specified" imports.

Under this differentiated BCA design, low-carbon out-of-state resources will be preferentially dispatched to supply the California market because these resources face lower GHG compliance costs. If more carbon-intensive resources are used to meet out-of-state demand, California's GHG accounting will underestimate the true GHG implications of imported electricity. To address this problem, a prohibition on resource shuffling was initially proposed. However, this proved impossible to implement. Ultimately, policymakers walked back the prohibition and issued a controversial list of market behaviors that were deemed acceptable. Ex ante analysis projected that permitted resource reallocation could result in substantial leakage (for example, Bushnell, Chen, and Zaragoza-Watkins 2014).[4]

III. The Simulation Model

To assess the GHG implications of California's chosen BCA design, we adapt a model of the western electricity market developed by Bushnell et al. (2017). We use detailed hourly load and production data for all generation sources operating within the US portion of the Western Electricity Coordinating Council (WECC). We simulate hourly outcomes in 2019, the first year for which hourly data from hydro, nuclear, wind, solar, and other renewable energy production are available in the Energy Information Administration Hourly Electric Monitor.[5]

Operating costs and emissions intensities for thermal power plants are calibrated using eGRID2018. Following Bushnell et al. (2017), the transmission grid is modeled using a DC flow approximation that links four WECC subregions (California, Northwest, Southwest and the Rockies). We calibrate region-specific hourly demand functions by setting the median slope consistent with an elasticity of 0.10 and the intercept to pass through the observed price

[4] California has been refining its approach to regulating GHG emissions from electricity imports within the smaller Energy Imbalance Market, which accounts for a small fraction (less than 5 percent) of imports.

[5] Additional model details are summarized in the online Appendix.

and quantity at each hour. We use a k-mean clustering algorithm to simplify the data into 100 weighted representative hours.

We solve for thermal plants' static operation decisions, assuming that firms operate competitively. The equilibrium outcome is that which maximizes consumer surplus less firms' operating costs (including GHG compliance costs) subject to generation and transmission constraints. We simulate hourly market outcomes under two benchmark cases and two BCA design alternatives as follows.

Complete Regulation.—In this benchmark case, all western electricity producers are regulated under the same carbon pricing regime. Let i index generating units characterized by constant marginal costs c_i, an emissions intensity e_i, and a capacity constraint $\bar{q}_i$. Under complete GHG regulation, the variable operating costs for all units is $c_i + \tau e_i$, where τ denotes the carbon price. We fix this price at \$17/ton. Although the California GHG price is determined endogenously, permit prices have been consistently near the price floor due to excess supply.

Incomplete Regulation.—In the second benchmark case, only producers in California are subject to the carbon tax. Out-of-state producers have no compliance obligation. This is a "worst case" for emissions leakage. Variable operating costs for out-of-state producers are defined as c_i regardless of where the electricity is consumed.[6] For California's producers, variable costs are $c_i + \tau \cdot e_i$.

Uniform BCA.—The carbon price in California is augmented with a fixed BCA. All imports into California are assigned the same default emissions intensity d. The marginal operating cost incurred by an of out-of-state producer is thus $c_i + \tau \cdot d$ when supplying consumers in California (and c_i otherwise).

Differentiated BCA.—This regime is designed to mimic California's more flexible BCA design. Importers can specify the carbon intensity of their out-of-state generation sources. Unspecified imports are assigned the default rate d. The variable cost incurred by an out-of-state producer supplying the California market is thus $c_i + \min\{\tau \cdot d, \tau \cdot e_i\}$.

These simulations capture some market elements in detail, such as short-run variable generation costs, hourly renewable energy production, and the costs of complying with the GHG cap-and-trade program. But we abstract away from other aspects. We use a stylized representation of operating costs, ignoring ramping costs and other dynamic considerations. We capture only a subset of the transmission and distribution system constraints that can limit how electricity flows through the system. We also fail to capture some nuanced restrictions and provisions that could serve to mitigate emissions leakage, such as limits on which resources are eligible as specified imports.

IV. Results

Figure 1 illustrates simulated GHG emissions, measured in tons of CO_2 per hour, across a range of policy design scenarios. The first benchmark at 19,460 tons/hour represents WECC-wide emissions under the coordinated policy that taxes all GHG emissions in the western US market. The second benchmark at 27,890 tons/hour represents WECC emissions under the incomplete carbon pricing regime that imposes no GHG compliance obligation on out-of-state producers.

We simulate emissions outcomes under the BCA regimes using a range of default emissions rates. We contrast these simulated outcomes against our stylized benchmarks and the GHG emissions outcomes we actually observe in 2019. In this short paper, we focus on three key insights.

First, regardless of the default rate chosen, the differentiated BCA has no moderating impact on GHG leakage; system-wide GHG emissions are indistinguishable from the incomplete regulation benchmark. Intuitively, zero-carbon resources outside California are preferentially allocated to meet demand for imported electricity when the default rate is set above zero.[7]

[6] Some resources located outside of California dispatch directly into a California balancing authority. For modeling purposes, we assume these resources are regulated *as if* they are inside California. For accounting purposes, we continue to classify these as imports.

[7] This finding is qualitatively consistent with Bushnell, Chen, and Zaragoza-Watkins (2014), who calibrate a similar model using data from 2007.

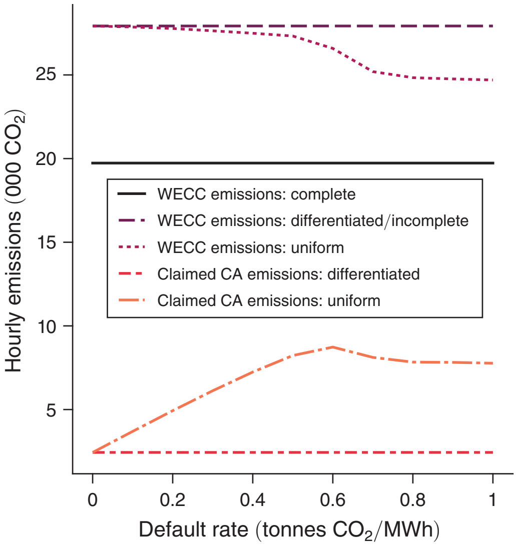

Figure 1. Claimed Emissions versus Emissions in California

Notes: Claimed emissions are those attributed to California electricity consumption. These are calculated by minimizing the burden based on taxed emissions. Actual emissions include emissions in California plus the flows coming from other regions evaluated at the average emissions rate.

Second, the uniform BCA regime can have a moderating impact on emissions leakage but only at higher default rates. As the default rate increases, California's demand for out-of-state imports falls. The default rate currently used in California has a relatively small impact on WECC-wide emissions (see Table 1, column 4) but a significant impact on the deemed emissions from imports and thus on the assessed GHG emissions associated with California electricity consumption. At default rates that correspond more closely to current, nonbaseload carbon intensities in neighboring regions (eGRID estimates nonbaseload carbon intensities above 0.7 for the Rockies and the Southwest in 2018), system-wide emissions are significantly reduced. However, a higher uniform default could be construed as discriminatory; out-of-state clean resources would face higher compliance costs as compared to carbon-comparable in-state resources.

Third, GHG emissions outcomes observed in 2019 depart significantly from our simulated outcomes. Table 1 compares ex post realized outcomes (in the first column) against our complete regulation benchmark (second column) and the calibrated policy simulations. As expected, 2019 WECC emissions (and the share of California electricity consumption met with imports) exceed the complete regulation benchmark by a significant margin. Notably, system-wide emissions in 2019 are 8 percent lower than the emissions simulated using a model that captures the most salient features of California's BCA design. We also observe fewer imports and higher deemed emissions for California than our model predicts. One interpretation is that hard-to-model regulatory provisions and operating constraints are having a moderating influence on resource shuffling and leakage.

V. Conclusion

California's GHG pricing regime offers a rare opportunity to investigate how a BCA is working in practice. The experience to date highlights important tensions between GHG accounting accuracy, market efficiency, concerns about trade protectionism, and implementation complexity.

A simulation model calibrated to represent the western electricity market—and the most salient features of California's GHG pricing regime—predicts that the differentiated border adjustment will be ineffective at mitigating emissions leakage regardless of the default GHG intensity chosen. The reason is that out-of-state zero-carbon resources can be preferentially dispatched to California, reducing California's deemed GHG emissions without changing the system-wide carbon footprint. In practice, however, realized emissions outcomes appear to outperform this worst-case scenario. One interpretation is that the more nuanced compliance requirements, difficult to capture in a market simulation model, are mitigating emissions leakage. More generally, this policy experiment in progress helps elucidate the complexity of implementing a BCA when sources are substitutable and carbon intensity is heterogeneous.

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Table 1—Summary Statistics of Simulated Outcomes

	Observed data (1)	Complete regulation (2)	Differentiated incomplete (3)	Uniform 0.428 (4)
Wholesale price ($/MWh)	35.04	39.53	31.65	31.93
California price	36.77	38.06	33.29	36.34
Rest WECC	34.46	40.34	30.70	29.46
WECC GHG emissions (000 tons)	25.52	19.46	27.89	27.21
California claimed emissions (000 tons)	4.56	7.31	2.81	7.53
Import share (of California GHGs)	0.34	0.23	0.05	0.57
California import share (of California GWh)	0.28	0.13	0.39	0.33

Notes: Hourly outcomes are based on 2019 data. All policies consider a California tax of $17 except for baseline. "Differentiated incomplete" means power plants can demonstrate less than the default rate of 0.428. "Uniform" means that all plants pay the default at 0.428.

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