IDB WORKING PAPER SERIES Nº [IDB-WP-01378]

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Integration and Trade Sector

August 2022

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Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library
Dolabella, Marcelo.
Fighting global warming: is trade policy in Latin America and the Caribbean a help or a hindrance?
/ Marcelo Dolabella, Mauricio Mesquita Moreira.
p. cm. — (IDB Working Paper Series ; 1378)
Includes bibliographic references.
1. Commercial policy-Environmental aspects-Latin America. 2. Commercial policy-Environmental aspects-Caribbean Area. 3. Environmental economics-Latin America. 4. Environmental economics-Caribbean Area. 5. Global warming-Latin America. 6. Global warming-Caribbean Area. 7. Greenhouse gas mitigation-Economic Aspects-Latin America. 8. Greenhouse gas mitigation-Caribbean Area.
I. Mesquita Moreira, Mauricio. II. Inter-American Development Bank. Integration and Trade Sector.
III. Title. IV. Series.
IDB-WP-1378

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Abstract

The dire prospects of global warming have been increasing the pressure on policymakers to use trade policy as a mitigation tool, challenging trade economists' canonical "targeting principle." Even though the justifications for this stance remain as valid as ever, it no longer seems feasible in a world that is already engaging actively in using trade policy for climate purposes. However, the search for second-best solutions remains warranted. In this paper, we focus on the climate benefits of tariff reform for a broad sample of Latin American and Caribbean countries, drawing on Shapiro's (2021) insights about the environmental bias of trade policy. Using a partial equilibrium approach and GTAP 10-MRIO data for 2014, we show that even though there is evidence of a negative bias toward "dirty goods" in half of the countries studied, translating this into actionable tariff reforms is plagued by interpretation and implementation difficulties, as well as by jurisdictional and efficiency trade-offs. There are also questions about their efficacy in curbing greenhouse gas emissions.

Keywords: Trade Policy, International Trade, Climate Change, Latin America andthe Caribbean

JEL Codes: F13, F14, F18, H23, Q56

* We would like to thank Juan Blyde, Kun Li, Danielle Trachtenberg, Christian Volpe, the participants in the WAITS 2022 seminar and the CINDES seminar held on March 11, 2022, and two anonymous referees for their helpful comments and suggestions. The views and interpretations in this study are strictly those of the authors and should not be attributed to the Inter-American Development Bank, its Board of Directors, or any of its member countries.

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1. Introduction

Like many of their colleagues around the world, trade ministers in Latin America and the Caribbean (LAC) can barely get a break these days. Backlashes against trade and globalization at home and abroad were swiftly followed by a public health crisis and geopolitical tensions that revived long-dormant calls for protection and autonomy. As if that wasn't enough, trade policy has also been called to play a role in the growing climate crisis, the social and economic impacts of which are potentially devastating, particularly for tropical regions such as much of LAC (Cruz Álvarez and Rossi-Hansberg 2021).

Even though one can hardly argue that LAC policymakers have all the answers to populist backlashes or calls for self-sufficiency (Moreira and Stein 2019), the climate challenge seems to be raising one of the thorniest questions to date: how can we use trade policy to "save the world," without undermining the gains of trade? In this paper, we explore tariff reform as one of the possible solutions to this puzzle. This study helps to fill a sizable gap in the literature: efforts to better understand the link between trade policy and emissions in LAC have been limited to a few papers that focus solely on Mexico's experience with preferential trade agreements (PTAs).[2]

Our analytical strategy follows Shapiro's (2021) insight that the structure of protection in different countries, which may owe to accident or design, can have a tangible impact on the carbon footprint of their trade by changing resource allocation across sectors and partners with different greenhouse gas (GHG) emission intensities. We are particularly interested in the question of whether this insight can be translated into tariff reforms that are: (i) practical, (ii) politically palatable, (iii) effective in delivering a meaningful reduction in emissions at home and abroad, and (iv) with low efficiency and rent-seeking costs.

Tariff reforms would fall into the category of second-best solutions. Trade economists have a long history of adherence to the "targeting principle," or the notion that, as Dixit (1985, 314) put it, "... a distortion is best countered, or conversely, deliberately introduced if desired as a non-economic objective, by a tax instrument that acts directly on the relevant margin." The relevant margin for climate change would be a market price of carbon that is well below its social cost. The first-best solution would be a Pigouvian tax on GHG emissions.

The logic behind this targeting principle remains intact, particularly if we consider the ubiquity of fossil fuel subsidies (IMF 2013), the uncertainty of the welfare effects of trade policy interventions (Kortum and Weisbach 2017), and the risk of environmental objectives being captured by protectionist interests. However, the gravity of the climate crisis and the political and geopolitical intricacies of a global carbon tax suggest that this is no longer a realistic approach. This is even

[2] For instance, Cherniwchan (2017) finds, using plant-level data, that NAFTA led to a significant reduction in the emissions of pollutants by US firms after the agreement. Gutiérrez and Teshima (2018), in turn, estimate that import competition, driven by PTA preferences, induced Mexican plants to increase their energy efficiency and reduce emissions while cutting investment in environmental protection.

more true in an environment where countries and trade agreements—skeptical of a global solution—are increasingly adopting unliteral carbon taxes or emissions trade systems.[3]

As is well-known, this kind of second-best solution comes at a price. The effectiveness of unilateral initiatives is undermined by a free rider problem, which is aggravated by second-order effects such as production moving to countries with laxer environmental regulations and lower fossil fuel prices—also known as carbon leakage (Copeland and Taylor 2005). To address this distortion, countries (particularly those in the developed world) are resorting to private and public policy solutions, which are also likely to create distortions of their own. They range from private, voluntary environmental labeling schemes (Elamin and Fernández de Córdoba 2020) to public environmental standards (EC 2020), enforceable environmental chapters in PTAs (Berger et al. 2020), and carbon border tariffs (Cosbey et al. 2019).

We are only just beginning to understand the trade and welfare consequences of these remedies, especially for developing countries (UNCTAD 2021, Bellora and Fontagné 2021). It seems clear, though, that they will put even more pressure on the already stressed multilateral trade system, which has long served LAC's interests. All of these approaches carry the risks of green protectionism and unduly raising trade costs, especially for developing countries (Plassmann et al. 2010). Carbon border tariff schemes are particularly plagued by questions about their consistency with the WTO principles of reciprocity and nondiscrimination (Bacchus 2021).

These concerns seem to be a strong enough motivation for a search for alternatives that are more likely to balance climate-, efficiency-, and political economy-related considerations. Shapiro's (2021) insights about tariff reform are particularly appealing in this context. His findings suggest that trade policy in most countries provides a subsidy to emissions because tariffs—driven by a political economy-motivated tariff escalation—favor trade in emission-intensive goods. The policy solution would be a tariff harmonization—an initiative that can be carried out unilaterally, without necessarily hurting WTO principles or commitments.

What's in it for LAC countries? To answer this question, we revisit the empirical exercise conducted by Shapiro (2021) to better identify emission biases in the region's trade policy and their implications for tariff reform. However, we make two important sets of changes. First, to be able to draw on a broader sample of LAC countries—20, instead of just Brazil and Mexico—and to use more recent data, we opt for the 2014 Global Trade Analysis Project multiregion input-output table (GTAP 10-MRIO) instead of the 2007 Exiobase database. We also extend the analysis to (i) include agriculture and mining and all GHG gases (not just CO_2), as these two sectors and their various emissions are key for LAC trade; and (ii) cover trade-related international transportation emissions using not only the input-output approach but also the bilateral flows method (Cristea et al. 2013). One major limitation that we could not overcome is the exclusion of emissions associated with land use: data and methodological constraints do not allow these emissions to be traced to specific sectors and, therefore, to trade flows.

[3] See World Bank Carbon Pricing 2021. https://openknowledge.worldbank.org/handle/10986/33809

The second set of changes involves looking beyond the goods' absolute embodied emissions and factoring in partners' average emission intensities—the "clean" partner dimension. The interplay between the goods and partner dimensions gives rise to "carbon comparative advantages," which can play a key role in the interpretation of the results and should be an important input for policy design.

Our findings show, first, that LAC trade has a carbon footprint large enough to merit a policy discussion—from a production perspective, it accounts for between 19.8% and 26.5% of the region's emissions, depending on whether household and land-use emissions are included in the denominator. However, these figures vary significantly across countries and are likely to be a lower bound because of the omission of land use mentioned above. Overall, unlike most of the developing world, the region tends to be a net importer of GHG emissions, which would make it an unlikely "beneficiary" of carbon leakage. The beneficiaries attract investments in high emission intensity goods—or simply "dirty" goods—and are thus more likely to be net exporters of emissions.

The second set of results focuses on trade policy's contribution to this footprint. The evidence suggests that at least half of the countries in the sample have lower tariffs for dirty goods. The other half have either a neutral stance or higher protection for these goods.

There is also evidence that these biases are mostly driven by the goods rather than the partner dimension of trade policy. Most countries seem to have lower levels of protection for their "cleanest" partners. There are, though, important nuances to the widely held intuition that there is a "carbon version" of the natural partner hypothesis—in other words, that PTAs are more likely to raise welfare if they involve neighboring countries (Krugman 1993). Distance is rarely a good predictor of the cleanest partners. For Colombia, for instance, Germany is a cleaner partner than Trinidad and Tobago on average.

If we follow Shapiro's (2021) interpretation, these negative (positive) correlations between tariffs and a good's emission intensity imply a subsidy to (a tax on) these emissions. MERCOSUR has the highest estimated subsidies, ranging from approximately US$10 per ton of CO_2 equivalent in Argentina and Brazil to US$7 in Uruguay and Paraguay. At the other end of the spectrum, Colombia, with a US$9 tax, leads the countries with taxes on emissions. To put these figures into perspective, recent estimates of the social cost of CO_2 range from US$56 to US$83 per metric ton (Interagency Working Group on Social Cost of Greenhouse Gases 2021). Trade policies in the region are either pushing countries in the wrong direction or making a modest contribution to closing the gap between the private and social costs of carbon.

The third set of findings concerns the expected gains of tariff reforms. This is where things get complicated. The interpretation that a negative bias toward dirty goods is a subsidy requires a restrictive assumption about countries' relative emissions efficiency—that is, the assumption that producing goods at home is more emissions-efficient than abroad. We show that is not always the case. For instance, the results of a partial equilibrium exercise, which simulates the impact of import substitution on emissions, suggest that this would have a negative effect in as much as 22% of LAC trade relationships, which account for 33% of the region's trade.

We also argue that there are other complications arising from jurisdictional and efficiency trade-offs. By eliminating the dirty goods bias, governments might be lowering global emissions but increasing emissions at home. This would undermine efforts to meet their own national emissions targets in multilateral environmental agreements, not to mention the collateral effects it would have on local air pollution, which is directly correlated with GHG emissions.

Likewise, eliminating emissions biases might imply raising protection to noncompetitive sectors, which already enjoy relatively high protection—a situation that is far too common in some of LAC's largest economies. This would worsen resource allocation, causing the negative effects on welfare and growth that are well-documented (Moreira and Stein 2019).

As if all these intricacies were not enough, the few general equilibrium estimates available suggest that the impact of tariff reforms on emissions would be modest and might not always run in the intended direction.

This paper is divided into six sections, including this introduction. The second section describes the main features of the data. The third goes over stylized facts about the region's overall and trade-related emissions. The fourth section outlines a framework for the relationship between trade policy and GHG emissions, using descriptive statistics and a partial equilibrium exercise to illustrate its relevance to the region. The fifth section provides an empirical analysis of the environmental biases of LAC's trade policy and assesses the prospects of tariff reform. The final section summarizes the main findings.

2. Data

As noted above, we use the 2014 GTAP 10-MRIO (the latest year available), which maps transactions across sectors and countries in a global economy. It covers a broader set of countries than the 2007 EXIOBASE used by Shapiro (2021)—147 countries and regions, including 20 from LAC—but contains just 65 sectors (45 tradables).[4]

Our GHG emissions data also comes from GTAP. It is country- and sector-specific and covers not just CO_2 emissions, but also those of methane (CH_4), nitrous oxide (N_2O), and a group of other fluorinated gases (F-gases), all converted to CO_2-equivalent (CO_2e) units.[5] Some of the GTAP 10-MRIO GHG emissions are only included in our analysis for descriptive purposes, namely those associated with land use, land-use change, and forestry (LULUCF), which reflect the impact on the so-called carbon stocks embedded in vegetation and soil; and household emissions, which relate to the burning of fossil fuels for personal transportation, cooking, heating, or electricity. The omission of land use in our analytical exercise is particularly significant given

[4] See Aguilar et al. (2019).

[5] F-gases are a family of gases containing fluorine: the main types are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). CO_2 equivalents are calculated by multiplying each gas by its respective 100-year time horizon global warming potential (GWP) relative to CO_2. For example, 1 kg of CH_4 emitted has the same potential to warm the atmosphere as 25 kg of CO_2. These values are updated according to the latest scientific estimates. This report uses the GWP from the Fourth Assessment Report (AR4), IPCC (2007) because these are the values reported in the GTAP data.

its importance for most LAC countries (see below), but it reflects the fact that assigning these emissions to specific sectors and their trade flows is practically impossible (Wood 2017).

By combining GTAP's emission data with the transaction flows of the global MRIO data, we calculated a total emission intensity rate for each sector and country—that is, the amount of GHGs emitted per US dollar produced. This value contains not only direct emission requirements (direct resources used/burned for production) but also the indirect emissions coming from the supply chain (resources used/burned in the production of inputs for this industry). Formally:

$$ei^{total} = ei^{direct}(I - A)^{-1} \qquad (1)$$

where ei^{direct} is a row vector containing the direct emission intensities—tons of CO2e emitted per US dollar of gross output—of each sector and country. This vector is multiplied by the global Leontief Inverse ($(I - A)^{-1}$) to obtain total emission intensities (ei^{total}).[6] For example, the ei^{direct} of the chemical industry captures the emissions used by the chemical industry to produce fertilizers (direct), but also the emissions embodied in the electricity used as an input in the production of fertilizers (indirect). The use of an MRIO allows foreign intermediate production linkages to be included in the analysis.

The database includes emissions related to international transportation, a key component of trade-related emissions. For most of the analysis, we rely on the input-output approach, with international transportation emissions assigned to the country supplying the transportation service.[7] The exceptions to this are the partial equilibrium exercise on import substitution and the discussion on clean partners, which require transportation emissions and bilateral trade flows to be better aligned. For this exercise, we used the transportation emission intensity data from Li (2021), which allocates transportation emissions to importing countries (measured as the amount of CO_2 emitted in transporting a good from country *c* to country *p* per US dollar of trade).

Lastly, tariff data comes from the CESIFO-World Bank database (Teti 2020) and consist of applied rates—that is, most favored nation (MFN) and preferential tariffs.

3. LAC's Trade-Related Emissions: Stylized Facts

Before addressing the central question of this paper—the role of trade policy in GHG emissions—it is worth establishing some facts about the relevance of this. It seems particularly important to have a sense of the size of the problem. How relevant are trade-related emissions for countries in the region, including both goods and services?

Our estimates suggest that they can hardly be ignored no matter the angle they are viewed from (figure 1).[8] From a production perspective—that is, considering only what was produced

[6] See appendix A for a detailed description of these calculations.

[7] GTAP assigns international transportation fuel usage based on international services trade data—see van Leeuwen and McDougall (2010).

[8] In 2018, global GHG emissions reached approximately 50 billion tons of CO_2e, and LAC contributed 7.18% of these emissions (3.6 billion tons of CO_2e). The region's largest economies, Brazil and Mexico, are also the largest emitters, accounting for 2.55% and 1.55% of total global GHG emissions, respectively. They are followed by several South American nations, namely Argentina (0.78%), Venezuela (0.42%), Colombia (0.39%), Chile (0.24%), and Peru (0.18%), according to the most recent data (EDGAR v6.0). F-gases are not considered in these figures.

domestically for external consumption, including international transportation—they account for between 19.8% and 26.5% of the region's emissions, depending on whether household and land-use emissions are included in the denominator. From a consumption perspective—that is, emissions generated abroad and consumed domestically—they have a similar magnitude.[9] These production and consumption estimates are somewhat lower than those for global trade-related emissions.[10]

These regional figures are likely to be lower-bound estimates—particularly for countries whose exports are intensive in natural resources (e.g., agriculture, livestock, forestry, and mining)—because, as mentioned earlier, it is almost impossible to trace the link between emissions and land use accurately.

Although this overview of emissions in LAC is illustrative, it conceals significant cross-country heterogeneity. The share of trade in production emissions—excluding those from land use and household consumption—ranges from 77% in Trinidad and Tobago to 18% in Peru. This variation is even more pronounced once all emissions sources are included, particularly land use, whose importance varies significantly across countries in the region. This pattern of wide variation is also more prominent from a consumption perspective, with the trade-related contribution of most countries sitting above the region's average, which is heavily influenced by its largest countries.

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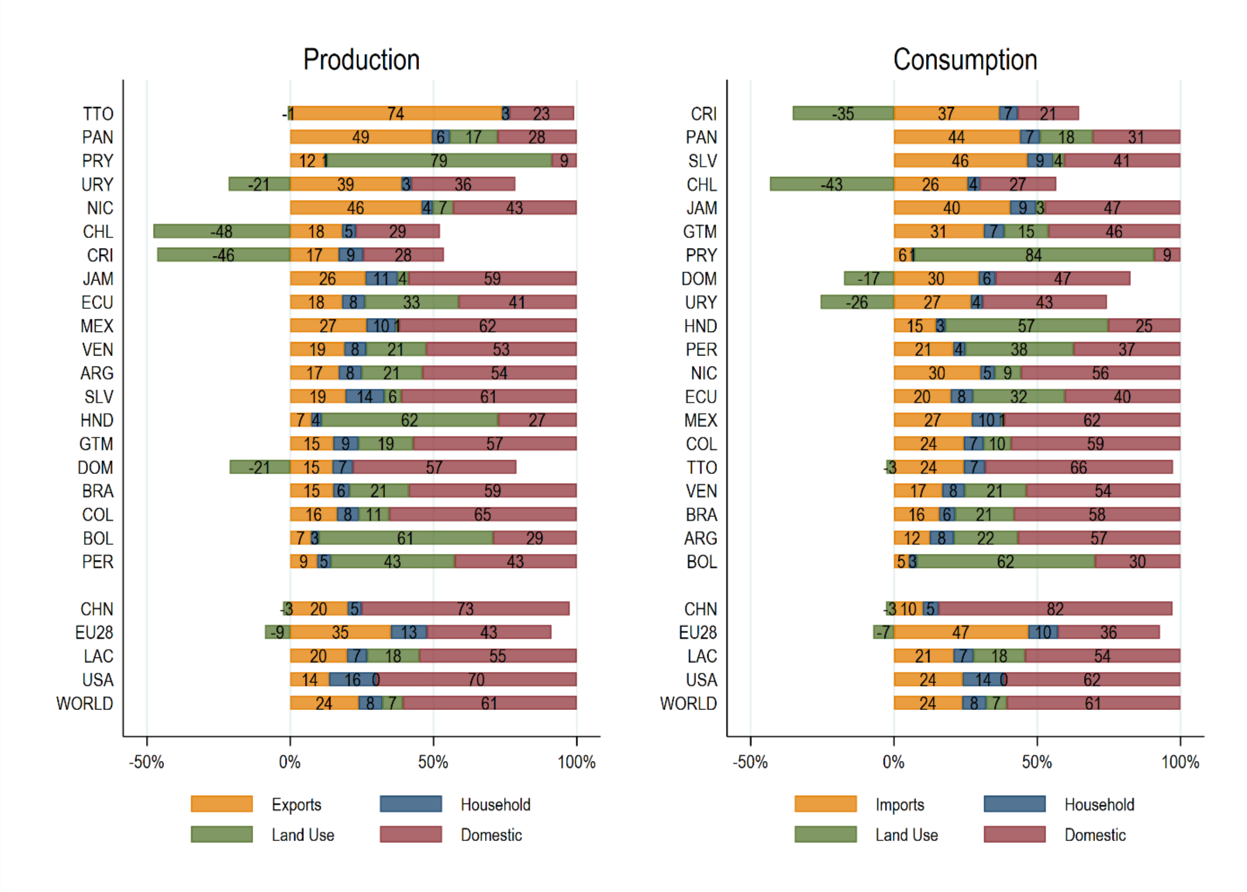
[9] Li (2021) arrives at similar estimates, using a different methodology that only includes domestic inputs and a different data source (EORA). She finds that LAC's export-related emissions reached 25% in 2014 (excluding household and LULUCF emissions), 24% of which originated in international shipping. Cristea et al. (2013) place the share of transportation in LAC's export-related emissions at 24%for 2004. They only include direct domestic and international transportation emissions.

[10] Peters and Hertwich's (2008) estimate for the world in 2001 is 21.5% (excluding household and LULUCF emissions). Copeland, Shapiro, and Taylor's (2021) WIOD-based world estimate for 2009 is 29% (including only CO_2 and excluding household and LULUCF emissions).

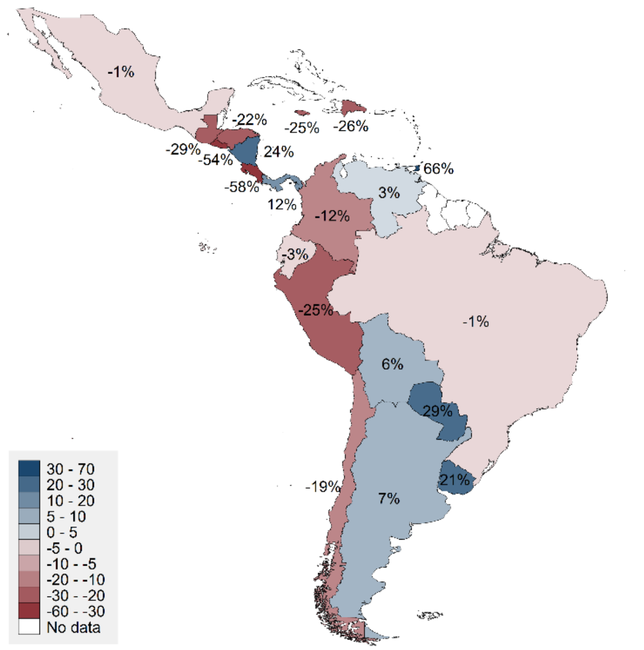
Figure 1. Share of Trade-Related GHG Emissions in Latin America and the Caribbean and Selected Regions. Production and Consumption Accounting.



Source: Own estimates based on data from 2014 GTAP 10-MRIO.
Note: LAC countries were ranked according to the share of exports (imports) in production (consumption) emissions, excluding land-use and household emissions. A negative value means that changes in land use reduced rather than increased emissions. Domestic emissions are emissions produced and consumed domestically. Exports are emissions produced domestically and consumed abroad. Imports are emissions produced abroad and consumed domestically. See section 2 and appendix A for details.

The differences in the rankings for the two accounting perspectives reveal LAC countries' different positions in emissions trade. In contrast with most of the developing world (Copeland, Shapiro, and Taylor 2021), LAC as a whole tends to be a net importer of GHG emissions—that is, consumption-related emissions are higher than production-related ones. This makes the region an unlikely recipient of carbon leakages. However, this situation owes mainly to the contribution of large countries such as Brazil, Colombia, and Mexico. There are a significant number of countries that are net emission exporters, such as Argentina, Paraguay, Uruguay, and Trinidad and Tobago (figure 2).

Figure 2. LAC's Net Exports of GHG Emissions. % of Production-Based Emissions.



Source: Own estimates based on data from 2014 GTAP 10-MRIO.
Note: Net exports equal total production-based emissions (emissions produced and consumed at home plus emissions consumed abroad) minus consumption-based emissions (emissions produced and consumed at home plus emissions produced abroad and consumed at home), as in Peters (2008). Negative values for net exporters mean they are net importers of GHG. See appendix A for details.

4. How Does Trade Policy Affect Emissions? A Framework and Stylized Facts.

Having established that trade makes a sizable contribution to the region's greenhouse gas (GHG) emissions, the burning question is what trade policy can do about it. Arguably, the size of the carbon footprint of LAC's trade is driven mainly by countries' comparative advantages and, to a lesser extent, their environmental and energy policies. Yet there are good theoretical and empirical reasons to believe that trade policies might be playing a significant role. By departing from free trade, they might be biasing the allocation of resources within and across countries, with potentially negative consequences for GHG emissions.

These effects might be coming from both the goods and partner dimensions of trade policy. Due to preferential policies, tariffs vary not only by product but also by partner. These variations, in turn, interact with differences in emission intensity across goods (amount of CO_2e units per US dollar of output) and partners (amount of CO_2e units emitted in trading with a particular partner).

As mentioned earlier, Shapiro (2021) draws attention to the goods dimension of these interactions. His findings show that most countries, including LAC's two largest economies (Brazil and Mexico), have tariffs that favor emission-intensive goods at the expense of their cleaner counterparts. This bias would imply a subsidy to GHG emissions and would result in higher global emissions because it would encourage: (i) imports of dirty goods from distant, more emission-intensive countries (the classical carbon leakage situation, but in this case driven by trade policy rather than environmental regulations) and (ii) the consumption of dirty goods, as they benefit from lower tariffs.

However, the exclusive focus on goods' absolute emission intensity (i.e., whether they are clean or dirty) can be misleading. For instance, the higher global emissions outcome hinges on the assumption that foreign suppliers are either less emission-efficient in the production of the dirty goods or that they become so once transportation emissions are allowed for. Or, more formally:

$$ei^{y}_{cg} - (ei^{y}_{pg} + ei^{t}_{pcg}) < 0 \qquad (2)$$

where ei^{y}_{cg} is the output emission intensity of good *g* produced in country *c*, ei^{y}_{pg} is the equivalent variable for partner *p*, $ei^{t}_{pcg}$is the transportation intensity (CO_2e units per US dollar shipped) of imports of good *g* by country *c* from country *p.*

As shown later, this is not necessarily the case. There might be situations where the country's output emission intensity is higher than that of its partner by a margin large enough to offset the transportation emission intensity (i.e., $\left(ei^{y}_{cg} - ei^{y}_{pg} \right) > ei^{t}_{pcg}$). If a country, say Trinidad and Tobago, is found to offer lower protection to dirty goods, say steel, but is less emission-efficient in its production (even when allowing for international transportation emissions), then we cannot rule out a scenario where this tariff structure contributes to lower global emissions (since output will shift to the more emission-efficient foreign producers).

It follows, then, that a bias against dirty goods is not sufficient evidence that trade policy contributes to higher global emissions. This is more likely to be the case if the structure of protection is biased against (i) goods where the country is relatively more emission-efficient than its partners and (ii) partners that are less transportation-intensive partners (shorter distances and/or cleaner transportation modes) and more emission-efficient (cleaner energy sources and/or cleaner technologies). In this case, imports will mostly be of those goods that the country has "carbon comparative advantages," sourced from the dirtiest partners.

To add another layer of complexity, these interactions between trade policy and emissions can involve thorny policy trade-offs involving domestic versus global emissions and carbon versus allocative efficiency. In the carbon leakage situation described in Shapiro (2021), for instance, the greater emission efficiency of the importer of dirty goods implies that the tariff structure might be pushing domestic and global emissions in opposite directions. Lower tariffs for dirty goods reduce their relative prices, pushing investment toward cleaner goods and an output mix that reduces domestic output emissions. However, shifting the production of dirty goods to dirtier suppliers abroad will increase global emissions.

While GHG emissions are global externalities, global cooperative solutions such as the Paris Agreement are based on so-called nationally determined contributions (NDCs). In this case, by eliminating occasional policy biases toward dirty goods, governments might be working against meeting their own national pledges. On top of this, they might be increasing local air pollution, which is directly correlated with GHG emissions—a potential jurisdictional trade-off.[11] Likewise,

[11] See Anenberg (2019) and Copeland, Shapiro, and Taylor (2021).

eliminating the tariff bias might imply raising protection for low-productivity, noncompetitive sectors and worsening resource allocation, leading to negative growth and welfare effects that have been well documented (Moreira and Stein 2019).

This all suggests that a robust emission-based assessment of trade policy cannot be unidimensional. It must look beyond the goods' absolute embodied emissions and factor in at least two other dimensions: relative emission intensities across countries (carbon comparative advantages) and the partners' average emission intensities (the clean partner dimension). It should also consider the implications that trade policy has for national emission targets and local pollution, as well as growth and welfare impacts. Before getting into the specifics of policy trade-offs, it is important to dig deeper into each of the main emission-related dimensions and explore how they interact with trade policies in the region.

Clean and dirty goods

How does emission intensity vary across goods? How can dirty and clean goods be told apart? We follow the literature by measuring the emission intensity of goods as the world average of total (direct and indirect) emissions (i.e., along the global value chain), weighted by output. Figure 3 shows the results of this calculation, which are like those presented elsewhere (Copeland, Shapiro, and Taylor 2021): the dirtiest goods include agricultural goods (livestock and rice), mining commodities (oil and gas), and intermediate manufacturing goods (nonmetallic minerals, iron, and steel). As argued earlier, the results for agriculture are likely to be underestimated as they do not include LULUCF emissions.

Although useful, this global ranking may conceal major differences in emission intensity across countries, which ultimately can give rise to emission intensity reversals—that is, goods that are considered dirty in one country but clean in another.[12] To address this issue, figure 3 includes two other emission rankings: one for domestic emission intensities, which consists of the output-weighted average of LAC countries' total emission intensities, including those embedded in foreign inputs; and one for imported emission intensities, which represents an import-weighted average of partners' emission intensities. It seems clear that these three rankings are highly correlated, which suggests that emission reversals are unlikely, although they cannot be ruled out at a more disaggregated country level.[13]

Clean and dirty partners

Just like goods, partners can also be ranked according to their emission intensity, which can vary according to factors such as distance, transportation mode, energy sources, and efficiency. This is done in figure 4, in which we compute an emission intensity indicator for the partners of selected LAC countries using measures of bilateral transportation (amount of CO_2e units emitted per US dollar of goods shipped) and direct output emissions (amount of CO_2e units emitted per US dollar of output). To estimate transportation emissions, we use Li's (2021) bilateral data, which follows

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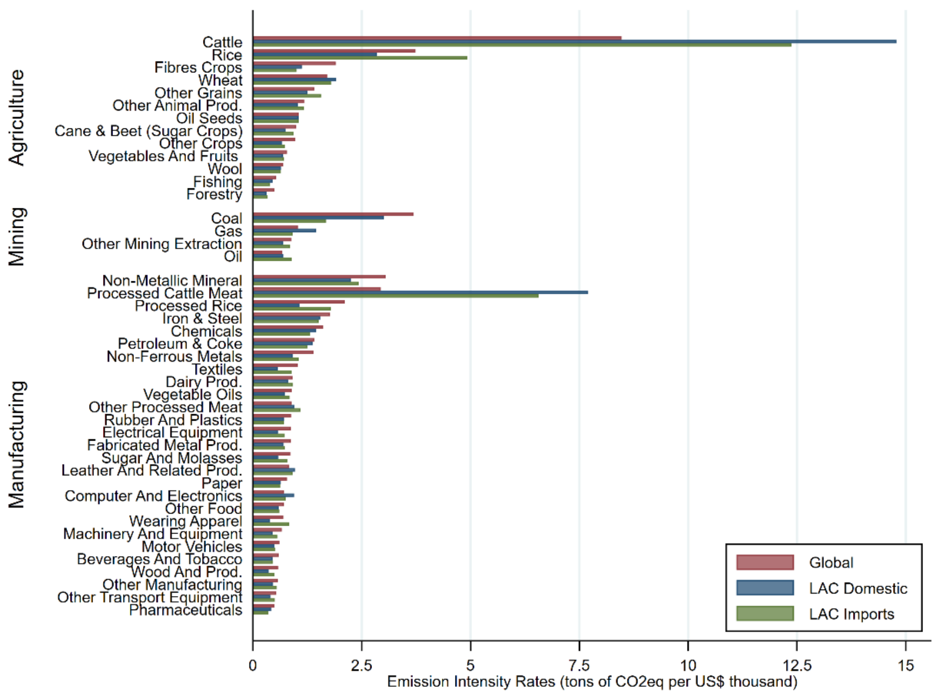
[12] This possibility is analogous to the factor-intensity reversal of traditional trade theory, where a sector might be, say, labor-intensive in one country but capital-intensive in another, leading to unexpected outcomes (Samuelson 1951).

[13] The Spearman correlation coefficient is 0.91 between global and domestic emission intensities, 0.94 between global and imported, and 0.92 between domestic and imported.

the bottom-up approach in Cristea et al. (2013), based on bilateral trade flows. We opted for direct emissions because of the difficulties in identifying bilateral transportation emissions in a total emissions framework.[14]

The results suggest that there are important nuances to the widely held intuition that there is a carbon version of the natural partner hypothesis, with distance being a good predictor of the cleanest partners, just like it would be for optimal partners in the formation of welfare-enhancing PTAs (Krugman 1993). For instance, for most countries in the region, there are distant Asian partners with a mean emission intensity that is lower than that of neighbors in North, Central or South America. More emission-efficient outputs and transportation modes may offset the disadvantages of distance.

Figure 3. Global, LAC Domestic, and Imported Emission Intensity by Sector



Source: Own estimates based on data from 2014 GTAP 10-MRIO.
Note: Global and LAC domestic emission intensities are output-weighted sector averages across all countries and LAC countries, respectively. Import emission intensities are LAC countries' import-weighted average of partners' emission intensities in each sector. Emission intensities include direct (output) emissions and indirect (domestic and imported inputs) emissions. Sectors are ranked by their global emission intensities. Land-use emissions and aggregated GTAP regions are not included. See appendix A for details.

[14] See van Leeuwen and McDougall (2010) and Peters, Andrew, and Lennox (2011) for the potential distortions in computing transportation emissions in the MRIO framework. Despite these potential distortions, the results using the MRIO approach point in the same direction.

Figure 4. Partners' Direct and Transportation Emission Intensity. Selected LAC Countries.
Tons of CO_2e per US$ of Output

LAC - Main Partners	ARG	BOL	BRA	CHL	COL	CRI	DOM	ECU	GTM	HND	JAM	MEX	NIC	PAN	PER	PRY	SLV	TTO	URY	VEN
United States	0.80	1.36	0.55	0.56	0.49	0.47	0.47	0.50	0.52	0.52	0.47	0.63	0.52	0.52	0.51	1.12	0.52	0.47	0.72	0.48
Canada	0.97	1.43	0.86	0.84	0.73	0.52	0.52	0.54	0.90	0.90	0.52	0.72	0.90	0.90	0.77	2.45	0.90	0.52	0.60	0.62
China	0.63	1.46	0.55	0.55	2.46	0.56	0.56	0.54	0.57	0.57	0.56	0.56	0.57	0.57	0.54	1.60	0.57	0.56	0.52	0.54
Japan	2.70	2.78	4.78	2.49	2.44	2.79	2.79	2.62	3.33	3.33	2.79	2.46	3.33	3.33	2.49	3.34	3.33	2.79	2.53	2.42
Korea, Rep	2.74	2.55	1.54	1.51	1.63	1.62	1.62	1.96	1.94	1.94	1.62	1.68	1.94	1.94	2.18	3.09	1.94	1.62	1.50	1.55
India	1.42	2.28	1.40	1.43	1.42	1.42	1.42	1.42	1.44	1.44	1.42	1.76	1.44	1.44	1.42	1.97	1.44	1.42	1.38	1.42
Thailand	1.49	2.40	1.40	4.55	1.36	1.37	1.37	1.39	1.74	1.74	1.37	2.28	1.74	1.74	1.77	3.91	1.74	1.37	1.86	1.74
Taiwan	2.95	3.34	2.35	2.59	2.33	2.31	2.31	2.63	2.48	2.48	2.31	2.47	2.48	2.48	2.27	3.16	2.48	2.31	2.27	2.27
Malaysia	0.87	1.62	0.82	0.83	1.32	0.87	0.87	0.83	1.25	1.25	0.87	0.97	1.25	1.25	0.84	1.29	1.25	0.87	0.79	0.81
Vietnam	0.91	1.82	0.81	3.96	0.78	0.78	0.78	0.80	1.16	1.16	0.78	1.70	1.16	1.16	1.19	3.32	1.16	0.78	1.27	1.16
Indonesia	0.87	1.62	0.82	0.83	1.32	0.86	0.86	0.83	1.25	1.25	0.86	0.96	1.25	1.25	0.84	1.29	1.25	0.86	0.78	0.80
Singapore	0.79	0.60	0.46	0.34	0.11	0.57	0.57	0.29	0.37	0.37	0.57	0.29	0.37	0.37	0.46	0.55	0.37	0.57	0.10	0.13
Germany	0.85	0.90	0.84	0.92	0.62	0.34	0.34	0.54	0.33	0.33	0.34	1.01	0.33	0.33	0.81	0.46	0.33	0.34	0.40	0.53
Italy	0.82	1.17	0.56	1.67	0.77	0.56	0.56	1.11	0.55	0.55	0.56	0.65	0.55	0.55	0.67	0.57	0.55	0.56	1.59	0.79
Spain	1.85	2.13	1.33	1.68	0.61	0.60	0.60	1.37	0.60	0.60	0.60	1.76	0.60	0.60	0.95	0.84	0.60	0.60	0.98	1.04
France	3.62	5.46	3.41	2.08	3.07	2.98	2.98	1.89	2.88	2.88	2.98	3.30	2.88	2.88	2.46	7.48	2.88	2.98	1.85	3.01
United Kingdom	0.85	1.16	0.78	0.74	0.97	0.48	0.48	1.35	0.35	0.35	0.48	0.70	0.35	0.35	0.87	0.78	0.35	0.48	0.44	0.41
Switzerland	0.34	2.43	0.28	1.08	0.67	1.52	1.52	0.62	2.27	2.27	1.52	0.71	2.27	2.27	5.49	2.76	2.27	1.52	0.51	0.55
Russian Federation	7.82	1.84	0.93	12.53	10.23	0.86	0.86	1.20	1.10	1.10	0.86	10.11	1.10	1.10	1.33	1.68	1.10	0.86	1.00	1.61
Netherlands	0.99	2.31	0.93	0.68	0.61	0.75	0.75	0.84	0.31	0.31	0.75	0.98	0.31	0.31	1.08	2.14	0.31	0.75	0.42	0.78
Belgium	0.60	1.32	0.34	0.76	0.40	0.33	0.33	0.40	0.36	0.36	0.33	0.60	0.36	0.36	0.40	0.37	0.36	0.33	0.42	0.33
Sweden	7.73	7.65	1.45	6.95	4.78	5.98	5.98	6.40	3.17	3.17	5.98	5.83	3.17	3.17	1.41	2.93	3.17	5.98	3.40	7.40
Ireland	1.51	2.34	1.54	1.22	1.23	1.36	1.36	2.55	1.63	1.63	1.36	1.39	1.63	1.63	1.89	1.13	1.63	1.36	2.17	1.94
Austria	3.05	0.70	0.69	1.11	2.26	1.04	1.04	0.57	0.79	0.79	1.04	1.78	0.79	0.79	0.95	0.76	0.79	1.04	1.76	0.42
Turkey	0.81	1.30	0.48	0.52	0.52	0.49	0.49	0.75	0.48	0.48	0.49	0.60	0.48	0.48	0.46	1.42	0.48	0.49	0.46	0.46
Brazil	2.17	2.45		2.20	3.07	1.98	1.98	1.95	2.25	2.25	1.98	2.35	2.25	2.25	2.07	2.13	2.25	1.98	2.24	2.00
Argentina		1.31	0.98	1.01	1.04	1.26	1.26	0.95	1.12	1.12	1.26	1.68	1.12	1.12	1.05	1.06	1.12	1.26	0.89	1.21
Mexico	0.95	1.18	0.74	0.70	0.68	0.73	0.73	0.68	0.84	0.84	0.73		0.84	0.84	0.69	1.17	0.84	0.73	0.75	0.77
Chile	0.83	0.98	0.83		2.56	0.81	0.81	0.68	0.85	0.85	0.81	0.73	0.85	0.85	0.71	0.86	0.85	0.81	0.81	1.63
Colombia	0.93	0.87	1.25	0.73		0.68	0.68	0.74	0.71	0.71	0.68	0.71	0.71	0.71	0.71	1.72	0.71	0.68	1.34	0.79
Peru	1.36	0.79	0.88	0.75	0.77	0.96	0.96	0.75	0.82	0.82	0.96	0.87	0.82	0.82		1.01	0.82	0.96	0.90	0.99
Ecuador	1.00	0.60	2.15	0.52	0.49	0.69	0.69		1.20	1.20	0.69	0.44	1.20	1.20	0.53	1.92	1.20	0.69	0.60	0.47
Bolivia	2.20		2.07	2.01	2.06	2.16	2.16	2.07	2.16	2.16	2.16	2.58	2.16	2.16	1.92	1.98	2.16	2.16	2.09	2.47
Trinidad and Tobago	1.27	2.38	0.98	1.01	1.14	1.07	1.07	0.87	0.92	0.92	1.07	1.08	0.92	0.92	1.09	2.64	0.92		1.52	1.65
Uruguay	0.60	0.87	0.66	0.81	0.68	0.66	0.66	0.95	1.19	1.19	0.66	0.74	1.19	1.19	1.00	0.70	1.19	0.66		0.73
Guatemala	1.93	0.61	0.81	1.05	0.86	0.63	0.63	0.61		0.61	0.63	1.14	0.61	0.61	2.01	0.58	0.61	0.63	0.76	0.60
Costa Rica	0.79	1.91	0.50	0.54	0.66		0.59	0.40	0.45	0.45	0.59	0.60	0.45	0.45	0.61	2.16	0.45	0.59	1.04	1.17
Venezuela, RB	0.91	1.87	1.44	1.17	0.73	0.71	0.71	0.68	0.60	0.60	0.71	0.94	0.60	0.60	0.77	1.66	0.60	0.71	1.41	
Nigeria	1.01	3.21	0.97	3.02	1.76	1.07	1.07	1.17	1.05	1.05	1.07	3.22	1.05	1.05	1.48	1.24	1.05	1.07	1.08	1.37
Saudi Arabia	0.72	2.49	0.66	2.76	1.48	0.82	0.82	0.77	0.80	0.80	0.82	0.97	0.80	0.80	1.33	1.34	0.80	0.82	0.66	0.68

Mean
GHG Emission Rate
dER+itER

[3.20, 12.53]
[1.65, 3.20)
[0.95, 1.65)
[0.65, 0.95)
[0.00, 0.65)

Note: For each cell, we calculate the average emission intensity across sectors of production in the partner (row) country and transportation to a LAC (column) country. Emission intensity is here defined as the sum of direct output emission intensities (CO_2e units emitted per thousand US dollars of output) and international transportation emission intensities (CO_2e units emitted per thousand US dollars of goods shipped). Aggregated GTAP regions and countries with missing tariff data are not included.
Source: Own estimates based on data from 2014 GTAP 10-MRIO and Li (2021).

Carbon comparative advantages

The interaction between the goods and partner dimensions brings a third important source of variation to light—differences in emission efficiency between trade partners across different goods. This was already evident in figure 3, which showed marked differences in sectors' emission intensities across the three rankings. The comparison, for instance, between LAC's domestic and imported rankings suggests that the region is more emission-efficient in agriculture, except for livestock. The opposite is true for oil and gas, while the picture is mixed for manufacturing.

However, the regional averages behind these rankings hide even greater heterogeneity, as LAC countries differ widely in both energy sources and efficiency. This is clear in figure 5, which uses a relative efficiency indicator to capture the differences between total domestic and import emission intensities (trade-weighted across partners) for selected LAC countries across sectors. The picture ranges from Bolivia, which is less emissions-efficient than its partners in most sectors, to Peru, which excels at most activities in emission terms. In both cases—and in all the countries between the two—there is sufficient variation across sectors to give rise to carbon comparative advantages.

To better illustrate how these comparative advantages matter for trade emissions, we replicate a back-of-the-envelope, partial equilibrium exercise that was first conducted by Cristea et al. (2013). The objective is to simulate the impact of a move to autarky on direct output and international transportation emissions at the country-partner-sector level.[15] The partial equilibrium nature of the exercise comes mainly from the (unrealistic) assumption that there are no changes in the consumption of goods.

The impact is measured by the following expression:

$$\Delta E_{pcg} = \left[ei_{cg}^{y} - (ei_{pg}^{y} + ei_{pcg}^{t})\right]VAL_{pcg} \quad (3)$$

where ΔE_{pcg} is the change in emissions once imports of good *g* from partner *p* are replaced by the domestic output of country *c*. ei_{cg}^{y} is the output emission intensity of country *c*, ei_{pg}^{y} is the output emission intensity of partner *p*, ei_{pcg}^{t} is the transportation intensity of country *c*'s imports from country *p*, and VAL_{pcg} is the value of these imports. For trade relationships where the country's output emission intensity is higher than that of its partner by a margin large enough to offset the transportation emission intensity (i.e., $(ei_{cg}^{y} - ei_{pg}^{y}) > ei_{pcg}^{t}$), a move to autarky would increase emissions.[16]

[15] As in the discussion of the partner dimension, we focus on direct emissions because we can measure transport emissions related to bilateral trade more accurately.

[16] This is the situation of the red cells in Figure 5, but there the comparison is with the average efficiency across all partners. In this exercise, the analysis is at the country-partner-sector level and is only considering direct production and bilateral transport emissions.

Figure 5. Relative Carbon Efficiency by Sector. Selected LAC Countries versus Trade Patterns (%)

	ARG	BOL	BRA	CHL	COL	CRI	DOM	ECU	GTM	HND	JAM	MEX	NIC	PAN	PER	PRY	SLV	TTO	URY	VEN
Cattle	-114.2	-145.9	-89.0	-21.6	-91.7	136.0	-165.0	48.2	19.0	-35.9	-50.8	-97.5	-141.2	13.2	-98.4	-63.1	-62.2	-82.3	-39.6	63.8
Rice	-48.8	17.9	83.1	-63.3	36.9	136.4	-23.4	-11.4	144.4	134.8	229.3	71.5	101.4	190.2	44.5	92.7	159.4	9.0	25.7	64.9
Wheat	-54.1	6.9	-26.3	37.1	130.2	163.8	4.3	62.3	120.1	-20.8	172.7	-44.1	64.4	69.9	144.7	39.5	144.0	418.4	50.3	181.4
Other Grains (corn, barley, rye, oats and others)	-3.8	24.8	-5.1	-3.5	21.7	113.2	-19.5	70.7	59.7	23.3	199.2	6.6	55.9	103.8	110.3	29.7	48.8	223.3	-19.8	110.4
Fibres crops	-0.9	-71.8	8.9	12.4	1.9	123.3	47.0	92.4	73.2	-31.2	109.2	-62.7	36.9	26.6	27.4	110.6	-14.5	291.4	-2.4	30.6
Oil Seeds	-62.0	5.7	-59.0	76.6	74.6	52.2	92.5	191.3	74.4	-4.5	115.4	7.2	45.1	-28.7	114.5	84.3	75.3	303.2	12.6	114.4
Other Animal Products (swine; eggs; hides…)	18.4	-99.3	24.4	20.6	5.6	14.9	-42.7	-31.4	9.0	-46.1	-21.7	18.5	23.3	52.9	49.4	15.7	62.7	-19.4	-73.0	49.5
Cane & Beet (sugar crops)	-2.4	-41.9	-10.3	39.9	114.8	63.9	43.9	96.0	60.8	31.7	55.4	32.7	10.4	62.4	40.2	-31.3	-76.5	-7.5	13.2	104.9
Vegetables and fruits	-60.4	9.8	-20.4	54.4	53.4	67.4	58.0	-17.2	60.1	11.5	7.7	-29.0	14.2	63.8	62.4	46.4	78.8	322.4	64.8	100.9
Other Crops	13.3	59.0	-20.1	53.1	-0.4	90.5	82.5	44.1	58.2	41.5	101.7	36.7	42.9	-34.7	28.7	43.7	32.2	284.6	-15.9	130.2
Wool	44.1	-81.1	-44.2	31.3	4.7	112.4	18.1	-32.5	94.4	-0.9	2.9	-3.8	9.4	-11.1	-7.7	106.9	-2.5	315.2	149.4	-36.5
Fishing	-86.2	-172.3	48.9	66.6	20.6	-77.3	29.8	77.6	91.8	-21.0	9.7	-124.6	40.4	85.2	13.0	150.2	88.1	272.7	22.9	199.0
Forestry	-20.8	-193.0	43.2	45.3	42.4	142.7	-11.3	106.3	-112.7	23.7	-127.1	-7.8	-26.7	33.5	82.8	69.2	185.6	288.5	35.0	140.6
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Coal	76.1	64.8	-339.4	-179.6	171.2	205.9	32.0	134.3	29.0	51.9	32.7	-8.4	130.9	23.6	-29.4	136.2	87.8	47.1	173.6	-54.6
Gas	65.7	-41.2	57.1	156.8	88.4	16.6	-182.5	-26.1	-51.8	-59.9	-5.6	-128.0	-42.8	-257.9	43.1	-95.5	-55.4	-55.0	-13.3	-242.3
Oil	47.4	-40.6	56.1	102.7	53.5	13.8	-4.5	-20.8	-24.4	-72.3	25.5	-9.0	64.9	-276.1	66.5	-110.3	-67.9	-59.4	64.9	-75.8
Other Mining Extraction	-7.5	56.1	57.6	-87.9	48.8	47.4	-8.0	-97.8	92.1	-3.4	-167.5	32.9	-134.5	-169.0	72.1	0.2	-326.2	15.9	146.6	-3.3
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Processed Cattle Meat	-80.1	-159.7	-7.5	112.6	-115.7	97.4	3.2	-15.5	-43.8	-124.6	-12.6	-77.0	-109.7	166.7	95.4	-48.1	18.0	123.8	6.1	83.5
Manufacture of other non-metallic mineral prod.	-5.3	18.5	15.3	42.0	85.7	-42.1	-0.7	22.9	-6.2	31.5	-45.0	-57.0	-16.5	-91.2	97.3	58.6	60.7	-15.8	103.2	54.5
Iron & Steel	-45.3	-39.9	9.8	29.0	27.5	34.5	-4.7	-40.7	-10.4	-42.0	11.6	-3.6	-14.5	9.8	-56.9	77.9	40.5	-64.6	121.3	10.3
Manufacture of chemicals and products	0.5	-45.8	47.7	37.4	60.5	66.7	35.5	9.1	37.8	54.5	-102.8	-89.5	24.9	-34.4	78.8	44.8	59.0	-120.9	60.5	-51.9
Petroleum & Coke	-22.3	-23.0	13.4	-6.8	39.3	-89.7	68.6	-27.2	-22.8	18.4	73.3	-34.0	48.9	-190.8	20.9	-168.3	-18.5	-115.4	0.6	-63.7
Processed Rice	45.4	-55.1	70.5	110.7	-5.3	54.9	-129.4	6.2	13.1	29.4	-53.7	94.7	6.0	59.9	42.5	38.1	86.4	-71.2	16.9	-38.4
Manufacture of leather and related products	-65.6	-24.4	-11.5	34.6	5.5	48.7	28.3	17.0	53.5	-7.6	8.7	15.1	-62.7	49.6	119.2	14.6	74.2	-56.8	28.9	67.1
Other Processed Meat	-107.0	-88.3	26.6	44.1	21.0	-50.8	56.8	-5.8	36.4	-42.2	12.8	48.6	42.7	62.0	102.1	36.7	67.6	-36.6	-205.9	118.1
Manufacture of computer, elect., optical prod.	-31.5	-113.5	19.8	42.1	63.9	84.0	-37.2	-56.3	-111.6	60.3	-165.5	-38.1	29.3	8.6	79.3	30.3	28.6	-96.7	23.7	-42.5
Non-Ferrous Metals	28.3	69.1	-87.8	177.5	93.5	-1.5	14.0	-18.8	-27.8	-2.7	57.5	17.4	37.9	2.9	146.0	125.6	13.2	-236.1	58.3	-85.0
Dairy Products	-15.5	-27.3	-18.4	35.5	-59.6	-41.3	25.5	15.2	55.2	9.4	49.2	44.8	-51.3	33.3	84.8	41.5	99.7	15.7	40.8	4.4
Vegetable Oils	-45.1	-38.4	7.2	34.1	47.3	105.5	98.3	101.2	98.8	36.1	34.6	18.2	5.8	-69.2	48.9	63.3	53.3	127.0	17.7	41.1
Manufacture of rubber and plastics products	25.4	-86.9	31.8	-6.5	41.6	45.6	35.9	-38.2	35.7	29.4	-48.6	-44.8	14.8	16.1	52.2	20.5	61.0	14.6	49.8	-17.2
Manufacture of fabricated metal products	-28.2	-118.3	33.0	26.7	49.3	69.2	-39.3	-68.2	-38.4	-4.5	-38.9	-7.0	-9.5	-44.7	-23.4	36.0	8.1	-110.4	81.4	-1.7
Paper & Paper Products	26.5	-54.2	18.3	-51.0	23.1	38.2	-26.7	-5.5	-18.0	-24.9	9.7	-42.3	-10.8	10.9	121.8	50.6	28.1	-76.8	-18.9	31.9
Manufacturing of Other Food	-4.6	-37.8	2.7	45.7	-47.2	20.7	-40.3	25.0	25.8	-29.7	-25.8	6.6	-37.3	-30.9	27.0	27.3	41.2	25.8	-6.2	9.3
Sugar and molasses	1.8	-19.9	27.3	-4.1	109.5	63.4	32.9	-12.8	67.3	79.2	-4.6	83.9	20.3	-69.0	-58.4	8.1	-85.9	-75.9	15.1	80.0
Manufacture of electrical equipment	-55.6	-109.2	35.4	40.7	44.4	62.7	-15.6	-38.7	-43.0	-19.7	-26.1	18.6	12.5	15.7	104.4	59.2	21.2	-80.5	74.3	-31.5
Manufacture of textiles	55.2	-37.7	59.4	33.1	80.8	-14.3	33.4	26.6	62.3	-1.9	-31.4	10.1	-36.8	70.7	116.3	75.7	72.3	29.3	107.7	8.9
Manufacture of motor vehicles	16.0	-89.0	5.4	-42.3	47.0	30.7	-43.6	-36.4	-6.0	-35.2	-72.2	-10.7	-6.5	-3.4	81.0	-6.4	70.6	-99.2	38.6	42.9
Other Manufacturing (inc. furniture)	-24.0	-159.9	54.2	51.8	81.8	57.3	-64.5	21.6	-26.3	-35.6	-160.0	-25.5	-82.1	-31.7	20.9	-7.4	3.8	-173.7	79.5	-47.8
Beverages and Tobacco products	14.8	-32.0	-2.8	2.0	36.1	29.7	35.1	8.9	-12.0	-11.0	-41.8	-27.2	-19.2	-82.2	103.5	15.3	66.8	-16.2	12.7	16.3
Manufacture of machinery and equipment n.e.c.	-43.2	-124.6	31.6	-12.6	15.0	71.9	-29.2	-77.9	-63.1	-44.9	-67.0	30.4	-15.9	-21.4	53.2	17.2	-15.6	-114.2	57.5	-20.2
Manufacture of pharmaceuticals	-6.9	-90.3	14.6	-12.3	14.2	45.8	61.1	-100.3	21.1	3.0	-46.4	-82.5	-14.0	-64.2	17.3	-24.4	43.6	34.1	4.9	-23.0
Manufacture of other transport equipment	75.6	-105.8	15.8	-15.8	20.8	20.8	-6.0	-61.9	36.1	-19.7	-74.6	5.4	-30.1	-71.1	124.7	-12.3	109.5	-159.0	75.7	20.8
Manufacture of wearing apparel	79.2	-102.8	106.1	55.8	80.5	82.7	33.3	29.2	29.9	23.2	7.5	62.5	-84.4	47.9	97.1	38.2	92.0	-50.1	119.3	77.5
Manufacture of wood and products	17.8	-79.7	62.7	39.3	42.4	42.5	-73.8	40.9	-25.9	6.4	-30.3	-1.4	52.4	-2.8	101.0	21.9	84.8	-121.6	95.6	69.2

GHG Efficiency

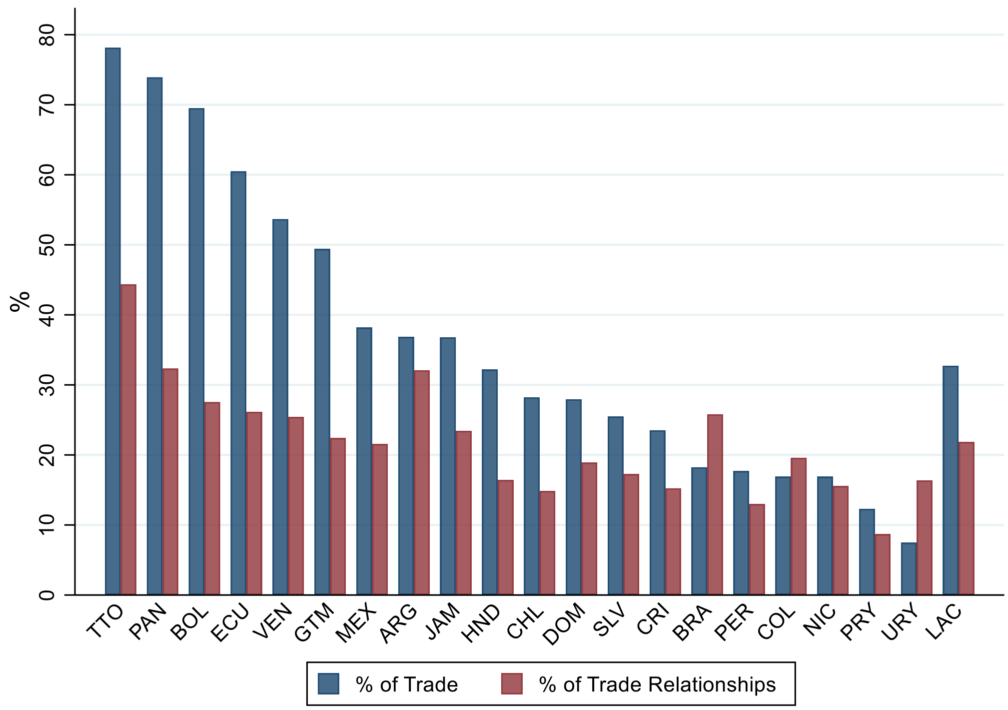
- [200, 500]
- [100, 200)
- [70, 100)
- [50, 70)
- [30, 50)
- [10, 30)
- [1, 10)
- [-1, 1)
- [-10, -1)
- [-30, -10)
- [-50, -30)
- [-70, -50)
- [-100, -70)
- [-200, -100)
- [-500, -200)

Note: Relative carbon emission efficiency is the log difference of the inverse of foreign and domestic total (direct plus indirect) emission intensities (CO_2e units per US dollar of output) times 100. Formally, $eff_{cpg} = \ln\left(\frac{1}{ei_{cg}}\right) - \ln\left(\frac{1}{ei_{pg}}\right)$. Foreign emission intensities are the partners' trade-weighted average. A GHG emission efficiency of 20% means that domestic production generates 20% more dollars' worth of goods per unit of CO_2e than its trade partners. Aggregated GTAP regions and countries with missing tariff data are not included.

Source: Own estimates based on data from 2014 GTAP 10-MRIO.

The results question the common perception that trade always increases emissions. In fact, a move to autarky would increase emissions in as much as 22% of LAC's trade relationships, which account for 33% of the region's trade (figure 6). This is the case for more than 60% of trade in countries such as Trinidad and Tobago, Panama, Ecuador, and Bolivia.

Figure 6. Percentage of Trade and Relationships in which Emissions Would Increase Under Autarky. Selected LAC countries (%)

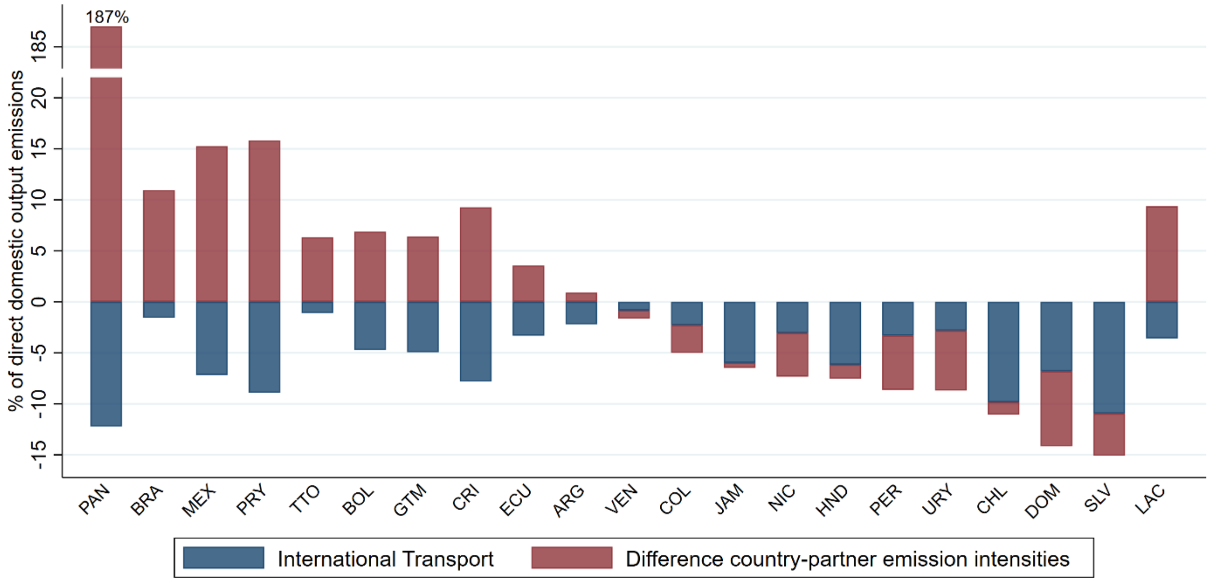


Source: Own estimates based on data from 2014 GTAP 10-MRIO and Kun (2021).

Note: This figure shows the percentage of trade relationships (country-partner-sector) and its share of trade where a move to autarky would increase direct emissions. That is, relationships where $\left(ei^{y}_{cg} - ei^{y}_{pg} \right) > ei^{t}_{pcg}$. See text for details.

Adding the changes across all the countries' relationships would give us the overall net impact of autarky on its emissions. This is shown in figure 7 as a percentage of countries' direct output emissions. In almost half of the countries in the sample, there are net increases in emissions, as reductions in efficiency more than offset the elimination of international transportation emissions. In cases such as Panama, Brazil, Mexico, and Paraguay, the increases are substantial. By contrast, in the other half of the sample, emissions are reduced as a result of different mixes of efficiency and transportation effects.

Figure 7. Net Impact of a Move to Autarky on Countrywide Direct and International Transportation Emissions. Selected LAC Countries. % of Overall Direct Output Emissions



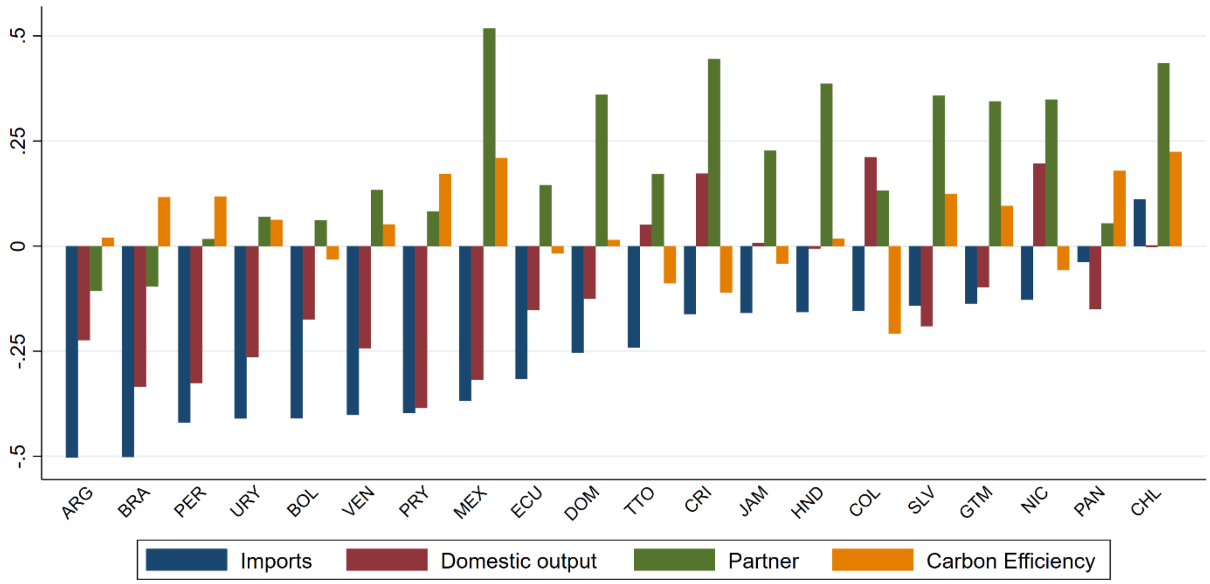
Source: Own estimates based on data from 2014 GTAP 10-MRIO and Li (2021).
Note: Rearranging equation 3 gives us $\Delta E_{pcg} = (ei^{y}_{cg} - ei^{y}_{pg})VAL_{pcg} + ei^{t}_{pcg}VAL_{pcg}$. The red bars represent the first right-hand term, the increase/decrease in emissions due to a move to autarky. The blue bars come from the second right-hand term, a reduction in emissions caused by the halting of the international transportation of goods. Adding the two bars renders the net effect. Emissions are normalized by dividing by total production emissions in each country, excluding household and land-use emissions.

5. LAC's Trade Policy and Its Carbon Biases

We have shown so far that (i) there is significant variation across the goods and partner emission dimensions, as well as in countries' relative sector emission efficiencies; and (ii) that these variations matter for trade policy outcomes. What remains to be seen is how far the region's trade policy is aligned with each of these dimensions. Does it favor or hamper trade in dirty goods? Does it favor or discriminate against dirty partners? Is it biased against carbon comparative advantages? Are there dramatic trade-offs between carbon versus allocative efficiency?

Before going into more rigorous and systematic answers to these questions, let's look first at what the more descriptive data suggests. Figure 8 shows how countries' applied tariffs are correlated with goods (by domestic output and imports metrics), partner emission intensities, and a carbon efficiency indicator, discussed earlier. For most countries, and particularly those from MERCOSUR, tariffs are negatively correlated with either measure of the emission intensity of goods. For some, though, the likelihood of a negative impact on global emissions seems mitigated by a trend toward applying higher tariffs to their dirtiest partners and goods in which they have the highest carbon efficiencies. Mexico is the best example.

Figure 8. Applied Tariffs Versus Total Goods and Partner Emission Intensities and Relative Efficiency. Selected LAC Countries. Spearman Rank Correlation



Source: Own estimates based on data from 2014 GTAP 10-MRIO.
Note: Each bar shows the Spearman correlation of applied tariffs and emission intensities (tons of CO_2e units per US dollar). The blue bar shows this correlation at the sector level, where tariffs and emission intensities are simple averages across partners. The red bars show this correlation for the sector dimension but this time comparing simple average applied tariffs to domestic emission intensities. The green bars reflect the correlation at the partner level, where tariffs and emission intensities are simple averages for each partner across sectors. Lastly, the yellow bars show the correlation between applied tariffs and our measure of relative carbon efficiency (as defined in the note to figure 5) at the sector-partner level. Aggregated GTAP regions and countries with missing tariff data are not included.

Chile is one of the few countries for which there is no conclusive evidence of a negative dirty bias. What makes it noteworthy is its clear, albeit small, bias in favor of cleaner goods (by the imports metric), which is reinforced by greater protection from dirtier partners and in favor of goods where it has carbon comparative advantages. There are other countries with conflicting results as they suffer from different degrees of emission intensity reversal (i.e., countries where the intensity rankings for domestic and imported goods differ significantly)—Costa Rica is the clearest example—a feature that makes evaluating trade policy even thornier.

An econometric exercise. Another, more rigorous way of looking at these correlations is to run an econometric exercise along the lines of Shapiro's (2021). The aim is not to establish any sort of causality but to test the statistical significance of all the dimensions and interactions discussed herein, as well as to estimate their environmental relevance. Unlike Shapiro, we restrict ourselves to applied tariffs. Even though there is little doubt that nontariff measures (NTMs) are an important part of trade policies in LAC, their impact can be ambiguous—for example, sanitary, phytosanitary, and technical standards may create trade. Moreover, ad valorem equivalents of

NTMs are not always robust to different methodologies (Cadot et al. 2018) and do not generate revenue—a feature that would complicate the interpretation of the estimates.

We run two specifications. The first closely follows Shapiro's (2021), and the equation—estimated separately for each of the LAC countries in the sample—takes the following form:

$$tar_{pg} = \alpha + \beta ei_{pg} + \varepsilon_{pg} \tag{3}$$

where, tar_{pg} represents the applied tariff rate faced by partner p in sector g, ei_{pg} stands for the GHG emission intensity per dollar produced by country p in sector g, and ε_{pg} is the error term.[17]

This specification brings together the partner and goods dimensions of trade policy discussed earlier. It can also identify their separate contributions by using either partner δ_p (for the goods bias) and sector γ_g (for the partner bias) fixed effects. Interpreting it is also straightforward. The intuition is that for each additional ton of CO_2e embodied in sector g, β US dollars would be collected from import duties. If positive, β can be interpreted as a tax on embodied CO_2, and if negative, as a subsidy.[18] To reduce the effect of outliers with exceedingly high emission intensities, we winsorize the goods-partner's emission intensity at the 95th percentile.[19]

The results are presented in figure 9.[20] A couple of points are worth noting. First, once we fully exploit the sector-partner dimension of data, LAC countries in the sample are evenly distributed between countries with a negative and positive tariff bias toward dirty goods. In between, there is a small group—Costa Rica, Jamaica, Dominican Republic, and Mexico—with a neutral stance (i.e., biases that are not statistically significant). Second, the biases are mostly driven by sector rather than partner variation, with two exceptions. These are Chile, whose MFN tariffs are mostly homogenous across goods and most of whose trade is covered by PTAs, and Mexico, whose trade is also heavily concentrated in PTAs. And third, the partner biases are mostly positive (i.e., higher tariffs for dirtier partners) although for a few countries they are neutral—Colombia, Trinidad and Tobago, and Peru, for example.[21]

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[17] For this section, we dropped countries that the GTAP aggregates into regions and a few countries with missing tariffs. This reduced the sample to 120 countries. See appendix A for details.

[18] This follows because tariffs rates are interpreted as the US dollar revenue collected for each US dollar worth of goods imported. A 10% applied tariff would be equivalent US$0.10 per US$1 of goods imported. Emission intensities, in turn, are measured as tons of CO_2e per US dollar of goods produced.

[19] Unlike Shapiro (2021), we run the regressions at the country-sector-partner level without aggregating emission intensities across the partner dimension. This exposes the sample to extremely large emission intensities, mostly from a few sector-countries whose economic significance in global production is minor. See table A1 in appendix B for the distribution of emission intensities. In appendix C.2, we report results without winsorizing, with different winsorizing levels, functional forms, and estimation methods.

[20] See appendix table A2 for detailed results of the estimation.

[21] We also run this specification including both sector and partner fixed effects (see appendix C.2). Most coefficients turned out to be not statistically significant, suggesting that little variation remains when we control simultaneously for these two dimensions. As in Shapiro (2021), we also run the benchmark specification with a continuous upstreamness variable. This generally leads to somewhat smaller coefficients, but not to a change in sign, with a few exceptions. There seems to be more than tariff escalation behind the results (See appendix C.3).

If we set aside for a moment the considerations made earlier about carbon comparative advantages and follow Shapiro's interpretation of the biases, the coefficients of the regressions can be seen as the dollar worth of the subsidies or taxes per ton of CO_2e that are implicit in each of the countries' tariff policies. In line with the previous correlation analysis, the results show that subsidies are highest in the MERCOSUR countries, where they range from approximately US$10 in Argentina and Brazil to US$7 in Uruguay and Paraguay. At the other end of the spectrum, Colombia leads the countries that tax emissions (US$9 per ton of CO_2e), followed by Panama and Nicaragua. [22]

To put these figures into perspective, most LAC countries have no carbon taxes or equivalent emissions trading schemes (ETSs). The exceptions are Mexico, Colombia, Chile, and Argentina, with effective taxes of approximately US$5 per ton of CO_2e or less,[23] although the social cost of carbon is estimated in the range of US$56 to US$83 per ton of CO_2e (Interagency Working Group on Social Cost of Greenhouse Gases 2021).[24] Moreover, the IMF (2019) estimates that for countries such as Colombia, Costa Rica, and Mexico, a carbon tax above US$70 per ton of CO_2e will be needed for them to meet their Paris Agreement pledges.

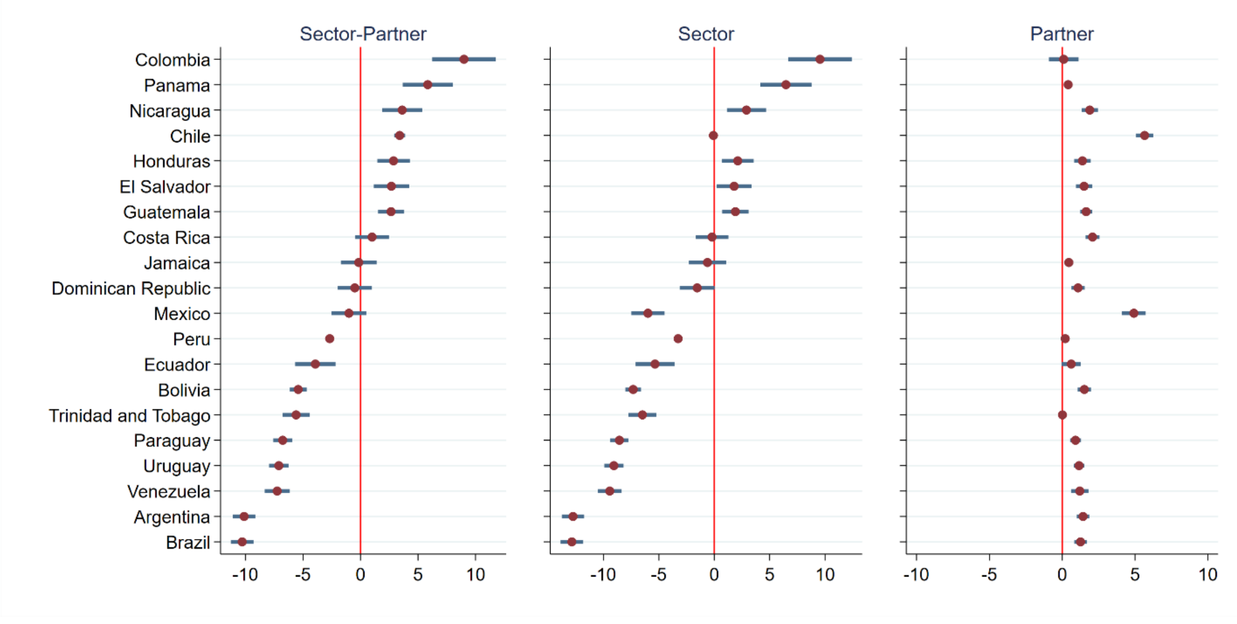
It is also worth comparing these potential trade policy subsidies with those that countries give directly to fossil fuels, as shown in figure 10. It seems clear that the benefits of eliminating these trade subsidies would pale in comparison to more direct measures aiming at closing the gap between the private and social costs of carbon.

[22] We find similar results for Brazil and Mexico using the Exiobase 3 database (2014 data), which has a finer sector-based disaggregation. The winsorized estimation, without fixed effects, points to carbon subsidies of US$5.11 and US$2.53 in Brazil and Mexico, respectively, at a 99% confidence level. As is shown in figure 9, this effect comes mainly from the sector dimension. See appendix C.4 for details.

[23] See World Bank (2021).

[24] Estimate for 2025 assuming a 3% discount rate.

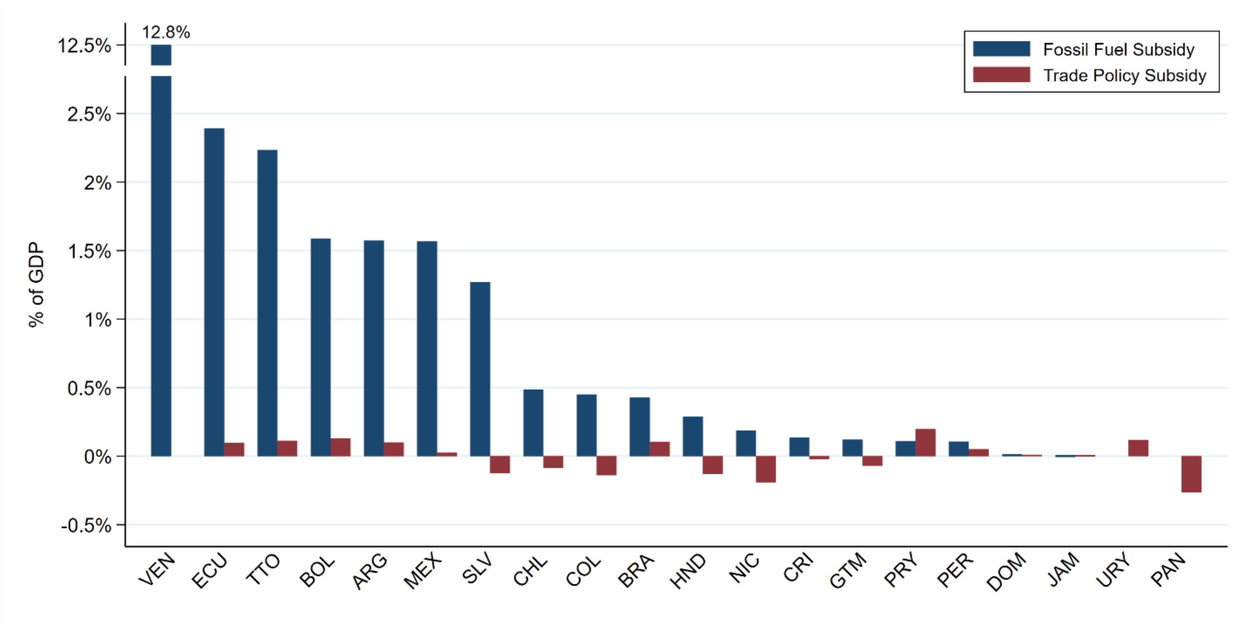
Figure 9. Covariances of Applied Tariffs and Goods Emission Intensities. Selected LAC Countries



Source: Own estimates based on data from 2014 GTAP 10-MRIO.

Note: The left-hand side variables are applied tariffs, and the right-hand side variables are total emission intensities (CO_2e per US dollar of output). Observations are at the sector-partner level. Estimates were performed for each LAC country. Emission intensities that were greater than the 95th percentile were replaced by this 95th percentile value. The left panel assesses the sector-partner dimension with estimates from equation 4. The middle panel assesses the sector dimension by estimating equation 4 with partner fixed effects. The right panel captures the effect over the partner dimension by estimating equation 4 with sector fixed effects. The blue bars represent the 95% confidence interval, calculated with robust standard errors. See appendix A, table A2 for the full results of the estimation.

Figure 10. Fossil Fuel and Potential Trade Policy Emission Subsidies as a % of GDP. Selected LAC Countries



Source: Fossil Fuel Subsidy Tracker data (IISD/OECD, 2021), World Bank, BACI-CEPII, and own estimates based on data from 2014 GTAP 10-MRIO.
Note: Calculation of trade policy subsidy—HS6 trade flows for 2019 were aggregated to the GTAP country pair-sector level and multiplied by their emission intensities to get a proxy of the emissions associated with imports. After aggregating at the importer level, we multiplied this value by our β country estimates from the left-hand panel in figure 9. Finally, we divided this value by 2019 GDP in current US$.

Overall, these results seem to leave no doubt that trade policies in the region are either pushing countries in the wrong direction or making only a modest contribution to closing the gap between the private and social costs of carbon. It is also tempting to jump to policy recommendations asking for the elimination of negative biases toward dirty goods or even the imposition of a bias toward their cleaner counterparts.

Things are not that simple, however. As argued earlier, the interpretation that a negative bias toward dirty goods is a subsidy to emissions implies an assumption that producing goods at home is more emission-efficient than doing so abroad. Moreover, there might be allocative and jurisdictional trade-offs. We use our second specification to further illustrate the complexity of this interaction between tariffs, the emission intensity of goods, and countries' relative emission intensity in the production of these goods. The equation takes the following form:

$$tar_{jk} = \alpha + \beta ei_g + \varphi\, eff_{pg} + \omega\,(ei_g * eff_{pg}) + \varepsilon_{pg} \quad (4)$$

We made two significant changes to the first specification:

(i) we use the (output-weighted) global average of the emission intensity of goods (ei_g) rather than that of the partner (ei_{pg}). This is because ei_g allows us to better illustrate the relationship between tariffs and the emission intensity of goods, which is conditional on the home country's relative levels of carbon efficiency. Since, by construction, ei_{pg} is one of the variables used to build eff_{pg}, its conditional tariff effects would not be linear.

(ii) we include a relative carbon efficiency variable, eff_{pg}, defined as the log difference of the inverse of the emission intensities of the home country and country p in sector g (discussed in figures 5 and 8), as well as its interaction with ei_g.[25]

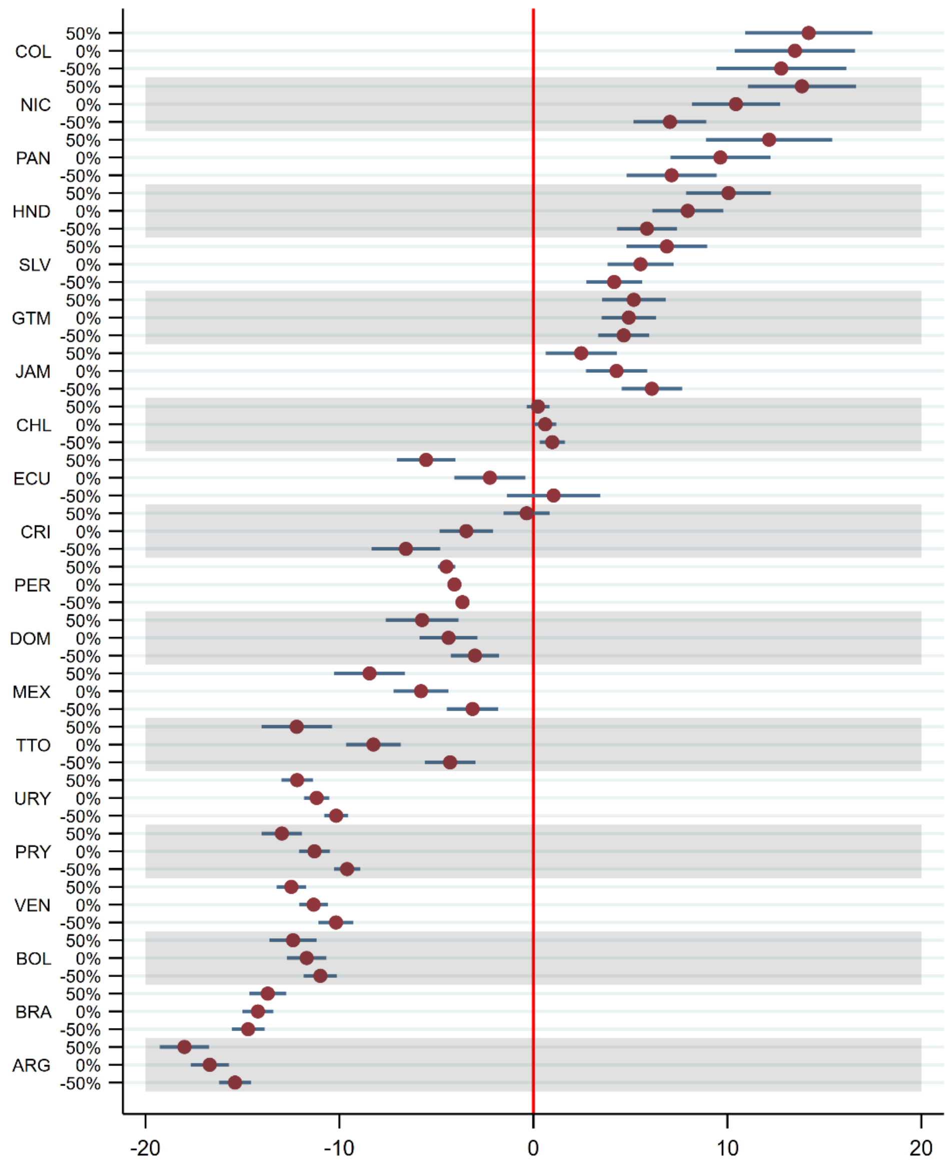
The results are shown in figure 11.[26] Generally speaking, they confirm the preliminary heterogeneous picture suggested in figure 8. At the high, positive end of the spectrum are countries such as Colombia and Nicaragua, where tariffs are higher for dirtier goods (positive β), but by being particularly higher for those goods where the country is more carbon-efficient (positive ω), it minimizes the risk of raising both local and global emissions.

At the lower end of the spectrum are countries such as Argentina and Paraguay, in which tariffs are not only low for dirty goods (negative β) but are particularly low for goods in which these countries are more carbon-efficient (negative ω), such that they might be maximizing the risk of importing goods from dirtier partners, thus raising global emissions. There is a third group of countries in an intermediate situation. Brazil and Costa Rica, for instance, have low tariffs for dirtier goods (negative β), but these tariffs are consistently lower for dirty goods that are produced more carbon-efficiently abroad (positive ω). This makes it less likely for countries in this group to import dirty goods in which they have carbon comparative advantages, which could lead to carbon leakage and an increase in global emissions. Jamaica is in a symmetrical position, in that its positive bias toward cleaner goods is mitigated by a negative correlation with relative carbon efficiency.

[25] More formally: $eff_{cpg} = \ln\left(\frac{1}{ei_{cg}}\right) - \ln\left(\frac{1}{ei_{pg}}\right)$. Log transforming has the advantage of reducing the influence of outliers and allowing small differences to be interpreted as percentage changes. This variable can be interpreted in two ways: i) it states how much more GHG-efficient local production is in comparison to foreign production (in percentages) and ii) it shows how much more GHG is emitted in partner p when compared to domestic production in c (in percentages).

[26] See appendix table A3, for detailed results of the estimation.

Figure 11. Covariances of Applied Tariffs and CO_2e Goods Emission Intensities Conditional on Relative Carbon Efficiencies. Selected LAC Countries



Source: Own estimates based on 2014 GTAP 10-MRIO.

Note: The dots represent the marginal effects of equation 5 emission intensity parameter ei_g, evaluated at diverse levels of relative carbon efficiency (50%, 0%, and -50%). Parameters were estimated by running country-specific regressions. Blue lines are 95% confidence intervals, with robust standard errors. See appendix A, table A3, for the full results of the estimation.

Viability and relevance of tariff reforms. Going back to the questions raised in the introduction, given all these intricacies and trade-offs, can we still find tariff reforms that (i) are practical, (ii) entail low efficiency and rent-seeking costs, (iii) are politically palatable, and (iv) bring about a meaningful reduction in emissions at home and abroad?

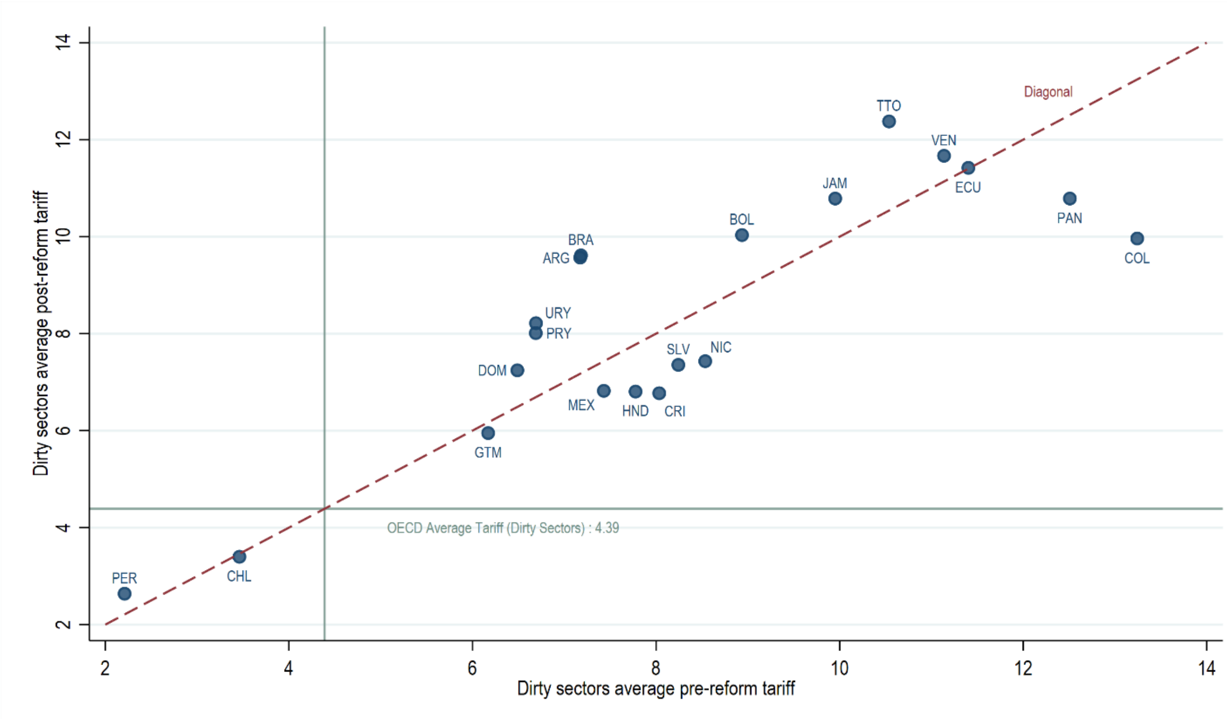
The honest answer seems to be that this is a long shot. It seems impractical to fine-tune tariffs according to the emission intensity of goods and the country's relative carbon comparative advantages while trying to balance efficiency costs. First, there are daunting data and legal constraints not unlike those faced by carbon border tariff schemes. It seems unrealistic—if not outright impossible—to expect to obtain accurate goods- and country-specific emission intensities for more than ten thousand tariff lines, which is the typical length of a country's tariff schedule. This is all the more true because there is a worldwide lack of consensus on how to measure these emissions at a very granular level, be that in the public or private sector (EC 2020). These blind spots would leave the door open for rent-seeking, which can defeat the whole purpose of the reform.

Even if this data were available, countries are constrained by their commitments to PTAs and the WTO. In theory, countries can use PTAs to explore the partner dimension of the equation and lower tariffs for their cleaner partners. In practice, the large stock of PTAs already signed by most LAC countries means that this would be limited to new agreements or would involve a costly and time-consuming renegotiation of existing ones, with unpredictable outcomes.

For similar reasons, opportunities in the goods dimension would have to be limited mostly to MFN tariffs, otherwise countries would also have to pay PTA renegotiation costs. In theory, MFN tariffs for dirty goods would be constrained by their consolidation commitments at the WTO, but most countries in the region still have a significant "tariff overhang." That is, the applied MFN tariffs are between 10 and 30 percentage points lower than those negotiated during the Uruguay Round (Bown et al. 2017).

The MFN constraints mostly come from efficiency considerations. That much is clear when we simulate a tariff reform along the lines suggested by Shapiro (2021)—that is, the elimination of potential emission biases by bringing applied tariffs to the bilateral mean for all trade relationships. This option ignores potential PTA and WTO constraints but has the merit of avoiding data and political economy difficulties by using a one-size-fits-all tariff rule. As figure 12 shows, a reform of this sort would lead one group of countries (those in the upper right quadrant and above the diagonal line) to further raise tariffs for dirty goods that are already relatively high. From an efficiency point of view, this would make a bad situation worse. It could also, as discussed earlier, aggravate jurisdictional trade-offs by increasing the domestic production of dirty goods.

Figure 12. Change in Applied Tariffs for Dirty Sectors After a Carbon-Neutral Reform (Bilateral Mean). Selected LAC Countries (%)

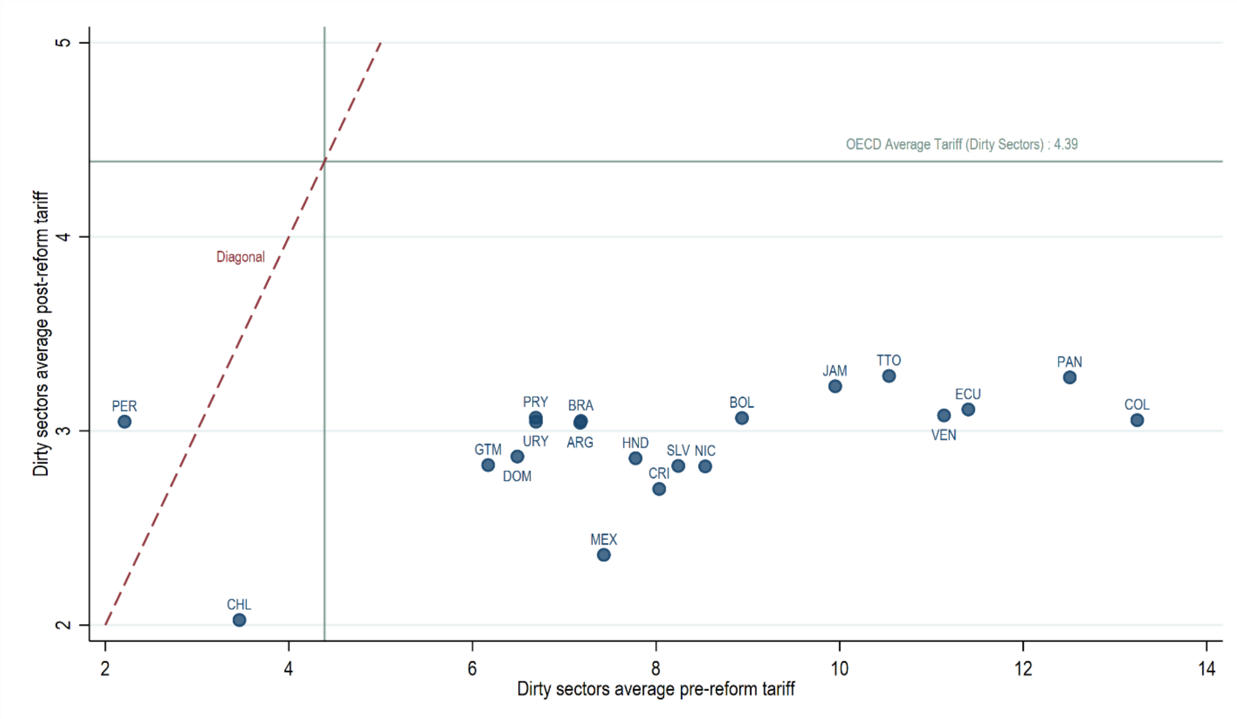


Source: Own estimates.
Note: The graph plots the average applied tariff across all partners and dirty sectors, before and after a tariff reform that brings applied tariffs to the bilateral mean for each country pair. Dirty sectors are defined as the 22 sectors with the largest emission intensities at a global level (weighted by global output). Aggregated GTAP regions and countries with missing tariff data are not included.

To overcome legal constraints and balance emission and efficient consideration, a more promising bet would be to bring all MFN tariffs not to the bilateral mean but to a lower benchmark, say, the OECD mean.[27] As figure 13 shows, this would combine the elimination of potential emission biases with efficiency gains, such that all countries except Peru would experience reductions in tariffs on dirty goods. The downside, though, would be the political economy viability of such a move. Despite the favorable environment of the 1990s and early 2000s, major trade liberalization has eluded some of the largest LAC economies, amid a complex political economy context (Cornick et al. 2022). Among those that advanced the most, only Chile managed to adopt a virtually uniform tariff—a rare feat at the global level, let alone in LAC.

27 For country-sectors whose preferential tariffs are higher than the OECD mean, we also change those preferential tariffs to the OECD mean to avoid renegotiating PTA benefits.

Figure 13. Change in Applied Tariffs for Dirty Sectors After a Carbon-Neutral Reform (OECD Mean). Selected LAC countries (%).



Source: Own estimates.

Note: The graph plots the average applied (MFN and preferential) tariff across all partners and dirty sectors, before and after a reform that brings all tariffs to the OECD mean. The postreform MFN tariff is the OECD average applied tariff across all sectors (3.31%). For country-sectors where preferential tariffs are higher than the OECD mean, we also change these to the OECD mean. Dirty sectors are defined as the 22 sectors with the largest emission intensities at a global level (weighted by global output). Aggregated GTAP regions and countries with missing tariff data are not included.

Aside from the difficulties of implementation, there is the all-important question of relevance. Can tariff reforms significantly reduce trade-related and overall national and global emissions? A precise answer to this question is beyond the scope of this paper. Given the multitude of dimensions involved, only a general equilibrium (GE) approach can offer more conclusive results. It is important, though, to keep expectations in check. As shown earlier, the trade-related share of LAC emissions is below 30%, which, even accounting for a potential land-use underestimation, imposes a low ceiling on reductions.

This seems to be confirmed by the few GE estimates available. For instance, Shapiro's (2021) results for the convergence-to-the-bilateral-mean reform is a modest 3.4% decrease for the sum of Brazil's and Mexico's emissions. The preliminary results of a companion paper (Dolabella and Moreira, forthcoming) are even more disappointing, suggesting that similar reforms would raise rather than curb emissions for most countries in the region.

6. Conclusions

The dire prospects of global warming have increased the pressure on policymakers to use trade policies as a mitigation tool. Trade economists have traditionally resisted the idea of using these policies for "noneconomic objectives" and have been staunch defenders of the "targeting principle." There is a good reason for this. This sort of intervention tends to be ineffective and create other costly distortions, notably by increasing countries' vulnerability to protectionist interests.

Unfortunately, the train seems to have already left the station. Frustration with multilateral environmental agreements has led some of the main world economies to take a variety of unilateral actions to effectively tax carbon emissions. This, in turn, raised the appeal of using trade policy tools, such as carbon border tariffs, to address ensuing "carbon leakage." As these initiatives entail legal challenges and the risk of further distortions, there is a need for better alternatives to balance climate-, efficiency-, and political economy-related considerations.

Shapiro's (2021) seminal insights about the environmental biases of trade policy seem to offer a smarter, more practical approach to reducing carbon leakage and the carbon footprint of trade. The devil, though, is in the details. Even though there is evidence of a negative bias toward dirty goods in almost half of the LAC countries studied, its translation into actionable tariff reforms is plagued by interpretation- and implementation-related difficulties, as well as by jurisdictional and efficiency trade-offs.

A more promising bet would be to combine MFN tariff harmonization with trade liberalization. A one-size-fits-all tariff rule would avoid data constraints and rent-seeking opportunities. The harmonization of MFN tariffs at OECD levels would make sure that the reform would steer clear of PTA and WTO constraints and prohibitive efficiency costs. However, furthering both trade liberalization and tariff harmonization is a challenging prospect in the current political economy. Moreover, no matter the shape that tariff harmonization takes, its impact on emissions is likely to be limited and may not necessarily be in the intended direction.

This all suggests that the quest for a second-best, less costly solution to minimize the region's trade carbon footprint continues. Abandoning the targeting principle to save the planet only makes sense if it really makes a difference.

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