Are Environmental Provisions reducing emissions within Global Value Chains?

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Abstract

This paper investigates the effects of trade policy and environmental provisions in Regional Trade Agreements (RTAs) using panel data over the period from 1990 to 2019 on carbon emissions embodied in trade flows. It focuses specifically on the role of Global Value Chains (GVCs) in driving CO2 emissions contained in bilateral trade in presence of trade policies and environmental provisions in RTAs. The main results show that RTAs with non-enforceable environmental provisions reduce CO2 emissions. In addition, we show that bilateral tariffs on intermediate and capital goods lower CO2 emissions more than tariffs on consumer goods suggesting that increasing tariffs in the former with reduce emissions faster. We also examine the interaction effects between RTAs with environmental provisions and participation of countries into GVCs. The results confirm that backward GVCs are more polluting than forward GVCs. In addition, RTAs with environmental provisions reduce pollution induced by GVC participation.

Keywords:

CO_2 emissions, Global Value Chains, Trade Policy, Regional Trade Agreements, Environmental Provisions.

JEL Classification: F15, F18, Q58, Q56.

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I. Introduction

One of the main public concerns in the twenty first century is the environmental outcomes of large-scale globalization. These concerns are also shared by scholars. They extensively investigated the question since the seminal work of Grossman and Krueger (1991). The authors find that trade liberalization is beneficial for the environment in the case of the North American Free Trade Agreement signed in the mid-nineties by Canada, Mexico and the U.S.A. Grossman and Krueger (1991) identify three channels through which trade impact environment: the scale effect, the composition effect and the technique effect. The scale effect reflects the increase in pollution driven by an upscale in production. The composition effect captures the shifts in countries' production towards goods in which they have a comparative advantage. Hence, pollution increases in countries that have a comparative advantage in dirty industries and decreases in countries whose comparative advantage lies in clean industries. The technique effect implies a reduction in the emissions since cleaner technologies lower the cost of environmentally friendly goods. The overall net effect is mitigated. For instance, Managi et al. (2009) find that the effect of trade on the environment was found to be positive for OECD countries, but not for developing countries, while Ren et al. (2014) show that China's trade openness increases carbon emissions. In addition to these three channels, trade impacts pollution through transportation. Since the products exchanged within global production networks cross borders many times before reaching their destination, international shipments needed to allow for global production networks are linked to growing carbon emissions. Recent studies put into perspective the role of trade policies on the environment. Shapiro (2021) finds that trade barriers are higher for downstream industries (closer to consumers and proxied by final products). Conversely, more upstream industries (proxied by intermediates goods) are more pollution-intensive. Another strand of literature has shown that environmental provisions (EPs) in trade agreements could play an important role to mitigate the environmental impact of trade liberalization (Martínez-Zarzoso, 2018; Martínez-Zarzoso and Oueslati. 2018; Baghdadi et al., 2013). Baghdadi et al. (2013) analyze the effect of EPs on CO_2 emissions of 182 countries over the period from 1980 to 2008 using the gravity model. Their findings suggest that countries that belong to the same RTA with environmental provisions have converged towards lower CO_2 emissions. Likewise, Martínez-Zarzoso (2018) analyzes the effect of EPs in RTAs on concentrations of suspended particulate matter (PM2.5), Sulphur dioxide (SO2) and nitrogen oxide (NOx) and finds that RTAs with environmental provisions have a positive impact on environmental quality related to the three pollutants. However, the results vary depending on the level of development of the countries considered, as confirmed by Martínez-Zarzoso and Oueslati (2018) for PM2.5. Similarly, Zhou et al. (2017) use panel data for 136 countries from 2001 to 2010 and show that RTAs without EPs harm air quality, whereas RTAs with EPs are linked to lower PM2.5 emissions.

The growing importance of Global Value Chains (GVCs) in the world economy has raised awareness on the consequences of GVC for environmental degradation, especially in developing countries (World Development Report (WDR), 2020). GVCs participation can harm or benefit the environment depending on the extent to which they use clean and environmentally friendly production techniques. Wang et al. (2019) find that participation in GVCs benefits the countries involved through the competition and technique effects that they generate. GVCs participation fosters the use of green technologies and eco-friendly products, which, in general, leads to reduced emissions. However, the scale effect generated by an early participation in GVCs could increase per capita carbon emissions. The impact of GVCs participation on emissions depends also on the type of activities performed within the chain. The overall impact of joining global production networks in terms of forward and backward participation in specific sectors on emissions depends on the pollution intensity of the activities performed. However, this question is still understudied to the best of our knowledge.

This paper investigates the effects of environmental provisions in Regional Trade Agreements (RTAs) on CO2 emissions with a particular focus on the role of Global Value Chains (GVCs) and trade policies. We estimate a gravity-type model for a panel dataset of 173 countries covering the period from 1990 to 2019. First, we explore the effects of RTAs with and without environmental provisions on CO_2 emissions embodied in the production of goods traded. Second, we examine the effect of tariffs on intermediate and final products on these carbon emissions. Third, we assess the impact of forward and backward participation on pollution and to what extent RTAs with environmental provisions reduce bilateral emissions contained in bilateral trade when partners engage either in forward or backward participation.

The remainder of the paper is organized as follows. Section 2 presents the methodology, the data and model specification. Section 3 details and discusses the empirical results. Section 4 summarizes the main findings and concludes with policy recommendations.

II. Methodology

1. Data and variables

We period covered in this study goes from 1990 to 2019. Carbon emissions data are collected from the Eora Global Supply Chain Database. CO2 emissions are measured in gigagrams (Gg; 1 Gg= 1kiloton (Kt)) and account for flows of embodied CO2 from each origin/emitter country to each destination/consumer country. The data on participation in GVCs are extracted from the UNCTAD-Eora Global Value Chain Database. This database makes use of global input-output tables to measure the extent to which production is globalized. The GVC participation index, indicating the level of integration into GVCs, constitutes the sum of the forward and backward participation indices. However, it is important to note that the GVC index can vary by year, as the extent of a country's participation in global value chains can change over time. The GVC participation index is expressed as a percentage of gross exports. Domestic value-added exports to a third country indicate forward participation in GVCs. Imports of foreign inputs for exportation constitute backward participation. In this case, value-added flows cross at least two borders in GVC trade (WDR, 2020). The GVC participation index[1] and its two sub-components are defined as follows:

GVC participation index = Forward GVC participation index + Backward participation index

where:

Forward GVC Participation Index = {Indirect Value Added (DVX)/Gross Exports} × 100

Backward GVC Participation Index = {Foreign Value Added (FVA)/Gross Exports} × 100

GVC variables are used to quantify the impact of GVC trade on air quality. To quantify the impact of the traditional international trade on carbon emissions, we collect data on imports of different categories of goods, such as intermediate goods, capital goods, and consumption goods. Imports are of the country originating pollution from the country of destination of carbon emissions. Here, we want to analyze how a country's own imports can have important implications for understanding its emission of carbon. Intermediate goods refer to the goods that are used in the production process of other goods, including raw materials, chemicals, and components. Capital goods refer to the goods that are used as fixed inputs and contribute to the production of other goods, including machinery, equipment, and vehicles. Consumption goods are the finished items bought and

[1] Casella et al. (2019) provide the details about the methodology applied to construct value-added data, which we used to calculate GVC indices.

consumed directly. They are sold directly to consumers, including food, clothing, and electronics. This data can be collected from World Integrated Trade Solution (WITS). It is possible now to estimate the effect associated with international trade in different categories of goods on carbon footprint. This information can then be used to develop appropriate trade policies to reduce the pollution associated with international trade.

Similarly, we include variables on the tariffs associated with the three categories of goods. This could provide useful insights into the impact of trade policies on air quality. By including variables on bilateral tariffs in our analysis, we can investigate how changes in tariff levels on imported goods in each category affect the emissions of carbon. Most-Favored-Nation (MFN) tariffs are the standard tariffs applied by a country to imports from all other countries, regardless of whether a trade agreement exists. One of the objectives of this study is to assess the effects of imposing MFN tariffs that are applied to imports on carbon emissions. Weighted average MFN Tariffs of goods data are from UNCTAD TRAINS accessed through WITS.

Furthermore, we use bilateral data on Preferential Trade Agreements (PTAs) from Hofmann et al. (2017) to account for agreements with and without environmental provisions. This database includes all PTAs notified to the World Trade Organization (WTO) until the year 2019. This dataset maps 52 provisions, including environmental ones, notified at WTO for agreements signed between 1958 and 2019.

The quality of institutions is key in reducing carbon dioxide emissions and, hence, reducing the level of environmental degradation in the countries that were analyzed. Nunez-Rocha and Martínez-Zarzoso (2018) include in their study Government Effectiveness “the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies” (World Bank (WB)) as a proxy of emissions institutional quality.

Also, Ibrahim and Law (2016) assess the impact of the interaction between the quality of institution and trade generated carbon emissions of 40 Sub-Sahara African (SSA) countries. They find that governmental reforms related to the quality of institutions improve environmental quality. Thus, we investigate the extent to which the quality of institutions, proxied by enforceable environmental provisions, decreases pollution.

The control variables used in the gravity estimations are geographical distance and dummy variables for common language and contiguity (sharing a common border), which were collected from the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII) database. The data on Gross domestic product (GDP) of the origin and destination countries are from World Development Indicators Database (WDID) of the World Bank. The countries considered in the empirical analysis are listed in Table A.1 in the Appendix. We provide a description of all the variables and the sources used in our analysis in Table A.2 in the Appendix.

Table 1 presents the summary statistics for our sample. The table shows the mean, standard deviation, minimum and maximum of the variables used in this study as well as the number of observations.

Table 1: Summary Statistics

Variables	Obs	Mean	Std.Dev.	Min	Max
CO2_odt	924000	1207.467	53806.07	0	9650000
Imports of capital goods_odt	389000	230000	2600000	0	2.66e+08
Imports of consumption goods_odt	448000	198000	2030000	0	2.33e+08
Imports of intermediate goods_odt	382000	160000	1200000	0	7.71e+07
Contiguity_od	914000	.017	.13	0	1
Language_od	914000	.138	.345	0	1
PTA_odt	924000	.09	.286	0	1
PTA_envlaws_odt	924000	.062	.241	0	1
PTA_envlaws_le_odt	924000	.026	.158	0	1
Backward_ot	924000	20.279	14.476	0	69.635
Forward_ot	924000	23.255	12.23	0	63.373
Backward_dt	924000	20.235	14.32	0	69.635
Forward_dt	924000	23.512	12.452	0	73.483
Ln distance_od	904000	8.709	.807	2.134	9.892
Ln gdp_ot	881000	17.026	2.27	10.67	23.788
Ln gdp_dt	871000	16.99	2.27	10.67	23.788

ln weighted average of MFN of intermediate goods_odt	220000	1.608	.961	0	5.778
ln weighted average of MFN capital goods_odt	229000	1.413	.968	0	5.017
ln weighted average of MFN consumption goods_odt	260000	2.203	.939	0	5.881
INTL_od	924000	.994	.075	0	1

2. Model Specification

To better understand the trade factors that influence CO2 flows between countries, we use the gravity model. We include factors such as tariffs, imports, GVC participation, and RTAs with and without environmental provisions.

Several research studies employ the gravity model as a tool to evaluate how regional trade agreements (RTAs) and environmental provisions affect carbon dioxide (CO2) emissions. For instance, Baghdadi et al. (2013) and Yao et al. (2019) both utilize the gravity model to investigate the impact of RTAs and environmental measures on carbon emissions. Similarly, Duarte et al., (2019) use the gravity model to explain the effect of economic, geographical and environmental factors on the flow of virtual water exports.

The dependent variable in our model is bilateral carbon emissions embodied in trade flows. Therefore, E_{odt} denotes pollution in terms of CO_2 emissions resulting from trade between country *o* and country *d* in year *t*.

The baseline model specification is given by,

$$E_{odt} = exp(\beta_1 PTA_{odt} + \beta_2 PTA\_envlaws_{odt} + \beta_3 PTA\_envlaws\_le_{odt} + \beta_4 \ln gdp_{ot} + \beta_5 \ln gdp_{dt} + \beta_6 \ln distance_{od} + \beta_7 \, language_{od} + \beta_8 \, contiguity_{od} + \pi_o + \theta_d + \vartheta_t) \, \varepsilon_{odt} \quad (1)$$

where *PTA_odt* denotes preferential trading arrangements between two countries, differentiating between those with non-enforceable environmental provisions (*PTA_envlaws_odt*), and those with enforceable environmental provisions (*PTA_envlaws_le_odt*). The gravity variables are the natural log of geographical distance, $lndistance_{od}$, $Contiguity_{od}$ is a dummy variable, which takes the value of 1 if the two countries share a common border and 0 otherwise; $Language_{od}$ takes a value of 1 if the two countries share a common language; *ln gdp_ot (ln gdp_dt)* is the gross domestic product. π_o, θ_d and ϑ_t are origin, destination and year fixed effects (FE), respectively.

Heid et al. (2021) suggest a new approach for analyzing the effect of non-discriminatory[2] trade policies on trade using the gravity model. They include intra-national trade flows. We follow their approach to estimate the impact of trade policies such as bilateral tariffs[3], while including intra-national carbon flows. This is because trade policies are only applicable to international CO2 flows, not domestic carbon flows. Therefore, even after applying country-pair fixed effects, unilateral trade policies can still be estimated.

Therefore, the second specification replaces the standard gravity variables by bilateral fixed effects, then we augment the model with tariff variables:

$$E_{odt} = \exp\big(\beta_1 PTA_{odt} + \beta_2 PTA\_envlaws_{odt} + \beta_3\, ln\,(1 + tariffs\ of\ intermediates_{odt}) \times INTL_{od} + \beta_4\, ln\,(1 + tariffs\ of\ intermediates_{odt}) \times PTA_{envlaws_{odt}} + \beta_5\, ln\,(1 + tariffs\ of\ capital\ goods_{odt}) \times INTL_{od} + \beta_6\, ln\,(1 + tariffs\ of\ capital\ goods_{odt}) \times PTA_{envlaws_{odt}} + \beta_7\, ln\,(1 + tariffs\ of\ consumption\ goods_{odt}) \times INTL_{od} +$$

[2] Non-discriminatory trade policies affect the volume of trade between two countries. Countries that have more open and non-discriminatory trade policies are likely to trade more with each other. Non-discriminatory trade policies can take many forms, such as reducing tariffs, removing non-tariff barriers, etc. These policies are where a country takes steps to liberalize its trade policies.

[3] Bilateral tariffs are import taxes imposed by country 1 on the goods of country 2. We use this methodology to drop any data on domestic flows.

$$\beta_8 \, ln\,(1 + tariffs\ of\ consumption\ goods_{odt}) \times PTA_{envlaws_{odt}} + \ \theta_{ot} + \pi_{dt} + \vartheta_{od}\big)\, \varepsilon_{odt}$$

(2)

$INTL_{od}$ is equal to one for international carbon flows and zero for intra-national emissions. $Tariffs_{odt}\ \times\ INTL_{od}$ is the interaction term between the MFN tariffs imposed by origin country on imports from destination countries and the international border dummy. It applies only to international flows and thus we can estimate the effects of trade policies and GVC indicators.

In addition, the third specification adds interactions between the $PTA\_envlaws_{odt}$ variable and the variables of international trade,

$$E_{odt} = \exp(\beta_1 PTA_{odt} + \beta_2 PTA\_envlaws_{odt} + \beta_3\, Imports\ of\ intermediates_{odt} + \beta_4\, Imports\ of\ capital\ goods_{odt} + \beta_5\, Imports\ of\ consumption\ goods_{odt} + \beta_6\, Imports\ of\ intermediates_{odt} \times PTA\_envlaws_{odt} + \beta_7\, Imports\ of\ capital\ goods_{odt}\ \times PTA\_envlaws_{odt} + \beta_8\, Imports\ of\ consumption\ goods_{odt}\ \times PTA\_envlaws_{odt} + \theta_{ot} + \pi_{dt} + \vartheta_{od})\, \varepsilon_{odt} \quad (3)$$

Furthermore, the fourth specification adds interactions between the $PTA\_envlaws_{odt}$ variable and the different GVC measures,

$$E_{odt} = \exp(\beta_1 PTA_{odt} + \beta_2 PTA\_envlaws_{odt} + \beta_3\, Forward\_o_t + \beta_4\, Backward\_o_t + \beta_5\, Forward\_d_t + \beta_4\, Backward\_d_t + \beta_6\, Forward\_o_t \times PTA\_envlaws_{odt} + \beta_7\, Backward\_o_t\ \times PTA\_envlaws_{odt} + \beta_8\, Forward\_d\,_t \times PTA\_envlaws_{odt} + \beta_8\, Backward\_d\,_t \times PTA\_envlaws_{odt} + \theta_{ot} + \pi_{dt} + \vartheta_{od})\, \varepsilon_{odt} \quad (4)$$

where *Forward_ot (Forward_dt)* indicates the forward participation index and *Backward_ot (Backward_dt)* denotes backward participation.

The interaction term between $PTA\_envlaws_{odt}$ and the GVC participation index is given by $Forward\_ot(\_dt)$ / $Backward\_ot(\_dt) \times PTA\_envlaws_{odt}$. Moreover, θ_{ot}, π_{dt} and ϑ_{od} denote origin-year FE, destination-year FE and country-pair (origin and destination) FE, respectively. Finally, ε_{odt} is the error term.

We are including country-pair fixed effects (FE) to control for endogeneity biases and we proxy multilateral resistance terms (MRT) with origin-time and destination-time dummies (Anderson and Van Wincoop, 2003) to control for all the potential bilateral trade relations available for a given country. The estimation technique used is Poisson Pseudo Maximum Likelihood (PPML), as recommended in the related literature to account for heteroskedasticity in the error term and for zeroes in the dependent variable.

III. Main Results

The models specified in the previous section are estimated for 173 countries over the period from 1990 to 2019. The results of equation (1) and (2), showing the average impact of PTAs (without and with environmental laws) and tariffs on carbon emissions, are presented in Table 2. Table 2 shows the findings of the gravity model in column (1) with income and time-invariant gravity variables and in column (2) with our variables of interest and bilateral fixed effects (FE). Next, results to account for the impact of tariffs, including MRT proxied with country-time and country-pair dummy variables and estimated using PPML, are shown in columns (3), (4) and (5), respectively. According to the results in column (1), flows of embodied CO_2 from each origin/emitter country to each destination/consumer country increase with GDP in origin and destination countries. The distance coefficient is significant and negative indicating that the larger the distance between countries, the lower the pollution. Contiguity, language, and PTA coefficients are positive.

In the columns (2-5), we estimate our model following the latest gravity literature. We consider that the estimations are robust and better than the estimates in column (1) because we apply multidimensional FE and bilateral FE. The coefficients of PTA are positive and statistically significant, indicating that signing trade agreements is linked to high pollution levels. However, the PTA_envlaws-odt –with environmental provisions– coefficients are always negative and significant. This indicates that whereas membership in PTAs unequivocally increases air pollution, this increase is reduced when the PTAs include environmental provisions (EP). This supports previous findings by Martínez-Zarzoso (2018) according to which Regional Trade Agreements (RTA) membership increases pollution when agreements do not include EP, but decreases pollution when EP are included. This is in line with Baghdadi et al. (2013) findings indicating that countries belonging to the same RTA with environmental laws reduce CO_2 emissions. Table 1 also illustrates that PTA_envlaws_le_odt coefficients are insignificant as shown in column 2. Consequently, we keep only PTA_envlaws_odt for the rest of specifications from column 3 to column 5. These last three specifications include tariffs by category of products (intermediate, capital and consumer goods) as well as the interaction of tariffs and trade agreements with environmental provisions. The results show that tariffs lower carbon emissions. Thus, a reduction in emissions is associated with imposing high tariff rates on imported goods. The impact of tariffs on carbon emissions varies depending on the type of the imported goods. Intermediate goods are goods used in the production of other goods. Increasing the weighted average of MFN tariffs on intermediate goods by 10 percent reduces carbon emissions by 0.7 percent. Moreover, capital goods refer to goods used in the production process. Increasing the weighted average of MFN tariffs on capital goods by 10 percent reduces carbon emissions by 1 percent. Finally, consumer goods are intended for final consumption. Increasing the weighted average of MFN tariffs on consumer goods by 10 percent reduces carbon emissions by 0.5 percent. This finding implies that higher tariffs reduce carbon emissions. Increasing tariffs on intermediate goods and capital goods have a greater impact on lowering carbon emissions compared to increasing tariffs on consumer goods. This is in line with Shapiro's (2021) results. Intermediate goods are often more pollution intensive than consumer goods. Therefore, imposing higher tariffs on intermediate could result in lowering emissions more than imposing higher tariffs on final goods. RTAs with environmental provisions do not decrease CO2 emissions in the presence of higher tariffs for any category of products. We could explain this result by the presence of two opposite effects. First, RTAs with or without environmental provisions generally reduce tariffs leading to higher emissions. Second, RTAs with environmental provisions lower these emissions. The overall net effect of RTAs with environmental provisions in the presence of tariffs lead to a non-significant effect.

Table 2: Tariffs, environmental provisions and CO_2 emissions

VARIABLES	(1) CO2	(2) CO2	(3) CO2	(4) CO2	(5) CO2
Ln gdp_ot	0.199***				
	(0.0503)				
Ln gdp_dt	0.264***				
	(0.0494)				
Ln distance_od	-0.839***				
	(0.0499)				
Contiguity_od	0.106				
	(0.110)				
Language_od	0.160*				
	(0.0829)				
PTA_odt	0.366***	0.342***	0.142***	0.143***	0.150***
	(0.0982)	(0.0371)	(0.0310)	(0.0298)	(0.0314)
PTA_envlaws_odt	0.0372	-0.109***	-0.122***	-0.112***	-0.121***
	(0.109)	(0.0414)	(0.0376)	(0.0369)	(0.0383)
PTA_envlaws_le_odt	0.213**	0.0462			
	(0.100)	(0.0328)			

INTL_od	-3.605***				
	(0.159)				
INTL_od × ln			-0.0765***		
(1+ weighted average of MFN of intermediate goods_odt)			(0.0144)		
PTA_envlaws_odt ×			0.00710		
ln (1+weighted average of MFN of intermediate goods_odt)			(0.0132)		
INTL_od ×				-0.100***	
ln (1+ weighted average of MFN capital goods_odt)				(0.0131)	
PTA_envlaws_odt ×				0.0282	
ln (1+ weighted average of MFN capital goods_odt)				(0.0196)	
INTL_od ×					-0.0528***
ln (1+ weighted average of MFN consumption goods_odt)					(0.0114)
PTA_envlaws_odt ×					0.00705
ln (1+ weighted average of MFN of consumption goods_odt)					(0.0135)
Observations	821,523	821,515	218,388	227,673	258,903
origin FE	YES				
destination FE	YES				
Year FE	YES				
origin year FE		YES	YES	YES	YES
destination year FE		YES	YES	YES	YES
Country-pair FE		YES	YES	YES	YES

Source: Authors' elaboration.

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 3 presents the results obtained from equation (3) that are estimated with PPML. Estimations of PTAs with environmental laws interacted with imports of capital, intermediate, and consumer goods, can provide insights into the potential impact of such agreements on carbon emissions. The interaction term between PTAs with environmental laws and imports of goods indicates the effect of these agreements on the environmental impact of trade.

First, results indicate that signing more PTAs increases pollution. This harmful effect on the environment decreases when we include environmental provisions in trade agreements. This result appears in the coefficients of PTAs with environmental laws which have a significant negative sign. In addition, the effect of imports of intermediate, consumer and capital goods on carbon emissions is positive and significant, indicating that importing goods harms air quality. However, this impact is weak. The interaction terms of the variables are negative suggesting that when imports increase carbon emissions, signing more PTAs with environmental provisions reduces this negative effect.

Although international trade has a relatively weak impact on emissions, it is still crucial to implement effective environmental provisions to minimize its negative effects.

Table 3: International trade, environmental provisions and CO2 emissions

VARIABLES	(1) CO2	(2) CO2	(3) CO2
PTA_odt	0.0555**	0.0915***	0.0549**
	(0.0258)	(0.0272)	(0.0244)
PTA_envlaws_odt	-0.0539**	-0.0867***	-0.0319
	(0.0264)	(0.0285)	(0.0248)
Imports of capital goods_odt	8.46e-10***		
	(2.74e-10)		
PTA_envlaws _odt × imports of capital goods_odt	-4.65e-10		
	(4.05e-10)		
Imports of consumption goods_odt		1.44e-09***	
		(4.13e-10)	
PTA envlaws _odt × imports of consumption goods_odt		-1.33e-09**	
		(5.35e-10)	
Imports of intermediate goods_odt			7.84e-09***
			(1.54e-09)
PTA_envlaws _odt × imports of intermediates_odt			-5.08e-09***
			(1.21e-09)
Observations	386,941	446,143	380,274
Origin year FE	YES	YES	YES
Destination year FE	YES	YES	YES
Country-pair FE	YES	YES	YES

Source: Authors' elaboration.
Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4 presents variables related to Global Value Chains (GVCs), which refer to international trade that involve multiple countries. These variables can provide insight into the relationships and interactions between different GVC variables and trade agreements with environmental laws variable. We show the results for the target variables resulting from estimating equation (4) that includes three set of dummy variables: pair FE, and inward and outward MRTs.

Forward_ot indicates forward participation in GVCs of countries where carbon emissions originate. In column (1), we see that forward participation of countries originating CO2 in GVCs increases carbon emissions. However, the results also indicate that the interaction term between the PTA and forward GVC participation index in origin countries has a negative significant coefficient. This means that a PTA with environmental provisions reduces the negative effect of forward participation in GVCs in countries originating carbon emissions. Furthermore, *Backward_ot* is the backward GVC participation index in countries originating CO2. *Forward_dt* and *Backward_dt* are the forward and backward participation indices related to destination countries, respectively. The impact of these variables on carbon emissions is the same as for *Forward_ot* (positive and significant). We notice from the magnitude of the coefficients that backward GVC participation contributes more to environmental degradation than forward participation.

The interaction term of *PTA_envlaws_odt* with the GVC participation variables (*Forward_dt, Backward_ot and Backward_dt)* is negative and significant. This suggests that the implementation of environmental provisions in preferential trade agreements (PTAs) can have a greater impact on reducing the negative environmental effects of GVC participation.

This underscores the importance of incorporating environmental considerations in trade agreements to mitigate the environmental consequences of global trade where the positive effect of environmental provisions appears in GVC trade (Table 4) compared to the traditional gross trade (Table 3).

Table 4: Forward and backward GVC participation, environmental provisions and CO2 emissions

VARIABLES	(1) CO2	(2) CO2	(3) CO2	(4) CO2
PTA_odt	0.337***	0.345***	0.339***	0.342***
	(0.0358)	(0.0365)	(0.0359)	(0.0366)
PTA_envlaws_odt	0.0430	-0.0291	-0.0185	0.0152

	(0.0427)	(0.0467)	(0.0427)	(0.0474)
INTL_od× Forward_ot	0.00630***			
	(0.000886)			
PTA_envlaws_odt × Forward_ot	-0.00465***			
	(0.000811)			
INTL_od× Backward_ot		0.0121***		
		(0.00122)		
PTA_envlaws_odt × Backward_ot		-0.00324***		
		(0.00103)		
INTL_od × Forward_dt			0.00575***	
			(0.000899)	
PTA_envlaws_odt × Forward_dt			-0.00254***	
			(0.000829)	
INTL_od × Backward_dt				0.0127***
				(0.00125)
PTA_envlaws _odt × Backward_dt				-0.00496***
				(0.00112)
Observations	923,812	923,812	923,812	923,812
Origin year FE	YES	YES	YES	YES
Destination year FE	YES	YES	YES	YES
Country-pair FE	YES	YES	YES	YES

Source: Authors' elaboration.
Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

IV. Conclusions

The link between trade and environmental degradation is an important issue that has garnered attention in the last years. Researchers have raised questions about how trade affects the environment, as well as how environmental policies may influence trade (WTO, 2004). Although many studies have examined the relationship between international trade and the environment, less attention has been paid to the environmental impact of participating in global value chains (GVCs) and importing intermediate inputs. Tariffs, as a trade policy, are important in this context because they can be used to address environmental concerns. This paper investigates how international trade, trade policy and participation in GVCs affects carbon dioxide (CO2) emissions when countries have PTAs with environmental regulations. Our study connects participation in global value chains (GVCs) through both backward and forward linkages, environmental provisions included in PTAs, tariff policies and the carbon footprint.

We find that while signing trade agreements is linked to high pollution levels, including environmental provisions in PTAs lower carbon emissions. In addition, tariffs increase emissions, as imposing high tariff rates on imported goods can lead to a decrease in emissions. The impact of tariffs on carbon emissions varies depending on the type of imported goods, with higher tariffs on intermediate and capital goods having a greater impact on lowering emissions compared to consumer goods. The results also suggest that the impact of imports of intermediate, consumer, and capital goods on carbon emissions is positive, but the effect is weak. However, signing more PTAs with environmental provisions can help reduce the negative effect of imports on carbon emissions. In addition, the results show that GVC participation increases carbon emissions, but the negative effect on air quality can be reduced by implementing environmental provisions in PTAs. Backward GVC participation has a greater impact on environmental degradation than forward participation. This study shows the importance of incorporating environmental provisions in trade agreements to mitigate the negative environmental effects of global trade and trade under GVCs.

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APPENDIX

Table A.1: List of countries

Afghanistan	Burundi	Gabon	Latvia	North Korea	Suriname
Albania	Cambodia	Gambia	Lebanon	Norway	Swaziland
Algeria	Cameroon	Georgia	Lesotho	Oman	Sweden
Andorra	Canada	Germany	Liberia	Pakistan	Switzerland
Angola	Cape Verde	Ghana	Libya	Panama	Syria
Antigua	Central African Republic	Greece	Lithuania	Papua New Guinea	TFYR Macedonia
Argentina	Chad	Guatemala	Luxembourg	Paraguay	Taiwan
Armenia	Chile	Guinea	Macao SAR	Peru	Tajikistan
Aruba	China	Guyana	Madagascar	Philippines	Tanzania
Australia	Colombia	Haiti	Malawi	Poland	Thailand
Austria	Congo	Honduras	Malaysia	Portugal	Togo
Azerbaijan	Costa Rica	Hong Kong	Maldives	Qatar	Trinidad and Tobago
Bahamas	Cote d'Ivoire	Hungary	Mali	Russia	Tunisia
Bahrain	Croatia	Iceland	Malta	Rwanda	Turkey
Bangladesh	Cuba	India	Mauritania	Samoa	Turkmenistan
Barbados	Cyprus	Indonesia	Mauritius	San Marino	UAE
Belarus	Czech Republic	Iran	Mexico	Sao Tome and Principe	UK
Belgium	Denmark	Iraq	Moldova	Saudi Arabia	USA
Belize	Djibouti	Ireland	Mongolia	Senegal	Uganda
Benin	Dominican Republic	Israel	Morocco	Seychelles	Ukraine
Bhutan	Ecuador	Italy	Mozambique	Sierra Leone	Uruguay
Bolivia	Egypt	Jamaica	Myanmar	Singapore	Uzbekistan
Bosnia and Herzegovina	El Salvador	Japan	Namibia	Slovakia	Vanuatu
Botswana	Eritrea	Jordan	Nepal	Slovenia	Venezuela
Brazil	Estonia	Kazakhstan	Netherlands	Somalia	Viet Nam

British Virgin Islands	Ethiopia	Kenya	New Zealand	South Africa	Yemen
Brunei	Fiji	Kuwait	Nicaragua	South Korea	Zambia
Bulgaria	Finland	Kyrgyzstan	Niger	Spain	Zimbabwe
Burkina Faso	France	Laos	Nigeria	Sri Lanka	

Table A.2: Variable description and sources

Variable	Description	Source
CO2_odt	Embodied flow_Gg CO2	Eora Global Supply Chain Database
Ln GDP_ot	Log of origin GDP (current US$)	WDID: World Development Indicators, World Bank
Ln GDP_dt	Log of destination GDP (current US$)	
Ln Distance_od	Log of weighted distance	CEPII
Contiguity_od	1=Contiguity	
Language_od	1=Common official or primary language	
PTA_odt	=1 if regional trade agreement	Dataset on the content of preferential trade agreements (FTAs) (Hofmann et al., 2017)
PTA_envlaws_odt PTA_envlaws_le_odt	=1 if there is at least one RTA with environmental provision mentioned in the agreement (le stands for legal enforceability)	
Forward_ot Forward_dt	Forward GVC participation index	UNCTAD-Eora Global Value Chain Database
Backward_ot Backward_dt	Backward GVC participation index	
Imports of capital goods_odt	Bilateral imports	World Integrated Trade Solution (WITS)
Imports of consumption goods_odt		
Imports of intermediate goods_odt		
ln weighted average of MFN of intermediate goods_odt	Log of (1 + Most-Favored-Nation (MFN) tariffs on intermediate goods_odt)	UNCTAD TRAINS accessed through WITS
ln weighted average of MFN capital goods_odt	Log of (1 + Most-Favored-Nation (MFN) tariffs on capital goods_odt)	

ln weighted average of MFN consumption goods_odt	Log of (1 + Most-Favored-Nation (MFN) tariffs on consumption goods_odt)	