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Environmental policy and the CO2 emissions embodied in international trade

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Abstract

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Keywords: CO2 emissions, international trade, panel data models.

JEL: C32, F18, Q56

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Environmental policy and the CO_2 emissions embodied in international trade*

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Abstract

As polices to curb carbon emissions are not implemented similarly across countries, a so-called 'carbon leakage' may offset domestic carbon reductions at the global level by redirecting CO_2-intensive production to places with less stringent environmental regulation. This article uses a standard gravity model with panel data to assess whether a tightening in environmental policy plays as an incentive to offshore highly polluting activities. Our results show no evidence of carbon leakage through international trade. On the contrary, stringent environment policy leads to a reduction in CO_2 emissions embodied in traded goods, both from the exporter and the importer's side. Such results are robust to focusing on trade between emerging and advanced economies. Emissions embodied in trade are rather explained by usual trade determinants, such as shipping costs or income, and the energy intensity of goods produced by the exporting countries.

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1 Introduction

As the stringency of climate policies differs across countries, the production of carbon-intensive goods may shift from the most constrained countries to "pollution havens", i.e. to countries with laxer policies. While data on emissions produced by the countries with most stringent policies point to some declines, they fail to take into account the emissions generated abroad and consumed domestically through imported goods. The emissions embodied in trade (around 8 billion tonnes in 2015) is very large, accounting for a quarter of total global emissions (approximately 32 billion tonnes), and advanced countries are generally net importers of CO_2 emissions, whereas emerging or commodity-producing countries are instead net exporters (Cezar and Polge, 2020). International climate commitments may contribute to this phenomenon as emissions targets differ by country, providing therefore an incentive to offshore highly polluting activities (Peters et al., 2011). This is usually referred to as 'carbon leakage'.

The issue of carbon leakage has been discussed quite extensively in the literature on climate change (IPCC, 2007). It is defined as the increase in emissions in a country A as a result of emission reductions in a country B which has implemented mitigation policies (Peters and Hertwich, 2008). Hence, introducing climate policy measures may increase the cost of regulatory compliance for country B's firms, giving a comparative advantage to their competitors operating in less regulated economies. To satisfy the final demand of its consumers, country B therefore compensates the shifting of the polluted good production by importing these goods from abroad.The carbon leakage phenomenon reduces the environmental benefits of the policy at the global level while potentially damaging the competitiveness of the economy that commits to emission reductions. Despite the emergence of coordinated commitments of emission reduction at global level (Kyoto protocol or Paris agreement) or regional climate policies (i.e. in the European Union), growth in global CO_2 emissions has remained strong and some studies suggest that the stabilization of emissions in advanced countries was partially the results of growing imports from emerging and developing countries (Peters et al., 2011).

The evaluation of the extent of carbon leakage has given rise to an abundant literature (see an overview e.g., in Branger and Quirion, 2014). However, most studies concern *ex ante* evaluation with Computable General Equilibrium (CGE) models. They evaluate theoretically the percentage of production that shifts from one country to another in response to a mitigation policy implemented only in the former country. While these studies find the leakage to range between 0 and 130%, the results are highly dependent on the modeling assumptions (IPCC, 2007; Peters and Hertwich, 2008; Branger and Quirion, 2014). Although these theoretical studies correctly identify the channels and the mechanisms of production shifting and their impact on trade flows, there is little evidence empirically – i.e. *ex post* – that production actually shifts as a result of environmental legislation (Cole et al., 2005; Spatareanu, 2007). On trade flows, the evidence is also mixed. For instance, Aichele and Felbermayr (2015) conduct an empirical *ex post* evaluation of the Kyoto protocol based on gravity models for the CO_2 content of trade. Based on panel data, they find evidence of carbon leakages, as binding commitments under Kyoto have increased committed countries' embodied carbon imports from non-committed countries by around 8%. However, in a study assessing whether he EU emissions trading system (ETS) causes carbon leakage in European manufacturing, Naegele and Zaklan (2019) do not find any empirical evidence in evaluating the effect of four measures of environmental stringency on both net trade flows and bilateral trade flows. Similarly, using a decomposition of US manufacturing greenhouse gas emissions, Brunel and Levinson (2021) do not find any evidence of offshoring either to or from the United States since 1990.

In this paper, we assess empirically the role of various determinants of the CO_2 emissions embodied in international trade and why they differ across countries. Following the literature on international trade flows, we rely on gravity models estimated on a large panel of countries. Our main goal is to assess whether differences in national climate-related legislation is a key determinant to explain the bilateral trade in CO_2 emissions across countries. In addition to traditional determinants of bilateral trade flows, we include differences in energy sources used – countries relying more intensively on fossil fuels generate more pollution (Davis and Caldeira, 2010) – as well as energy efficiency of productive apparatus, the degree of integration into global value chains, sectoral similarity and transportation costs (Shapiro, 2016). Our approach is similar to Aichele and Felbermayr (2015) orDuarte et al. (2018) as we also base our analysis on gravity equations. However, compared to these previous contributions, our approach is different in three ways. First, we use the data on CO_2 emissions embodied in trade flows produced by the OECD (Yamano and Guilhoto, 2020) on a large set of countries over a more recent period (2005-2015). Second, we include into our model more control variables in order to correctly identify the role of environmental policy in the exchange of CO_2 through international trade. We also pay special attention to all the econometric shortcomings found in previous contributions following Egger and Pfaffermayr (2003). Finally, instead of focusing on the participation or not to the Kyoto protocol, we rely on various measures assessing the environmental policy stringency across countries. These measures allow us to extend previous analyses to a wider range of policy actions that may be more relevant in the present context. In this respect, our approach is useful as with the adoption of the Paris Agreement, all countries that are parties have set themselves climate targets in a bottom-up process – the so-called Nationally Determined Contributions (NDCs). This differs from the Kyoto regime, where only the industrialised countries had fixed emission targets, while the vast majority of emerging countries had no obligations regarding their emissions. Hence, as each country individually formulated its NDC in line with its national circumstances, priorities and preferences, the differences in policy stringency may be more relevant. Our *de jure* environmental policy measures are also complemented with *de facto* measures based on environmental outcome, assessing the relative stringency of a country's policy in terms of *ex post* efficiency in reducing actual emissions.

Our results show no evidence of carbon leakage through international trade. On the contrary, a tightening in environmental policy leads to a reduction in CO_2 emissions embodied in trade. Such emissions are rather explained by usual trade determinants, such as shipping costs or income, and the energy intensity of goods produced by the exporting countries. These results are robust to changes in the estimation methods as well as alternative measures of trade costs. Moreover, we do not find any evidence of carbon leakage even when focusing only on bilateral exports from emerging economies to advanced ones. Therefore, the apparent imbalances in CO_2 emissions embodied in trade do not originate from differences in environmental policy but rather by usual specialisation motives. Although our results are related to a pre-Paris agreement context, they are also relevant from a policy perspective. Indeed, for the large majority of countries the existence of the NDCs means that carbon leakage would come with a consequence in the recipient country too. Indeed, as any leakage would no longer be just a positive boost that stimulates output in the domestic economy and increases foreign demand for domestic products, it would also come at a cost in terms of associated emissions and undesired deviations from NDC targets (Görlach and Zelljadt, 2019). Our results show that environmental commitments tend to decrease CO_2 emissions in all countries whether they are net exporter or net importers of emissions embodied in goods.

The paper is organised as follows. Section 2 presents the theoretical background and the modelling approach followed in this paper, sketching the gravity equations used in our empirical part. Section 3 presents then the data used in our analysis, detailing the OECD series of CO_2 emissions embodied in trade flows, the control variables used in the model as well as measures of environmental policy stringency. Section 4 reports and discusses our empirical results. Section 5 concludes.

2 Modelling the CO_2 emissions embodied in trade with gravity equations

In this section we first give an overview on how to introduce CO_2 emissions in standard gravity models before presenting thereafter its translation into our empirical equations

2.1 Introducing the carbon content of trade in gravity models

Since the seminal paper of Tinbergen (1962), trade gravity models have been traditionally used to investigate the main determinants of bilateral trade flows. Gravity equations characterize bilateral trade flows in terms of the size of economies and the distance between them. It has been the workhorse model of international trade empirical analysis owing to its stability and performance in explaining bilateral trade flows. The empirical validations of the gravity equation (Evenett and Keller, 2002; Helpman, 1987; Hummels and Levinsohn, 1995 is in accordance with the main theoretical models of international trade, including the Heckscher–Ohlin models and the models of the New International Trade Theory (Helpman and Krugman, 1987 or Anderson and van Wincoop, 2003).

Based on assumptions that: (1) consumers follow constant elasticity of substitution preferences, (2) all goods are differentiated by place of origin, and (3) trade costs are borne by exporters, Anderson and van Wincoop (2003) derive a theoretically-based gravity equation as follows:

$$X_{ij} = \frac{Y_i Y_j}{Y} \left(\frac{D_{ij}}{\Pi_i \Pi_j} \right)^{1-\sigma} \tag{2.1}$$

where X_{ij} denotes exports from country i to country j; Y represents world GDP, and Y_i and Y_j denote the GDP of countries i and j, respectively. D_{ij} denotes trade costs between countries i and j, and Π_i and Π_j represents respectively trade barriers for country i in exports and trade barriers for country j in imports. σ is the elasticity of substitution between all goods.

Using this theoretical model for trade flows, let us now see how to model emissions embodied in trade. CO_2 embodied in exports are calculated with the following equation:

$$C_{ij} = \mu_i \times X_{ij} \tag{2.2}$$

where C, a vector of emissions embodied in exports from country i to country j. It is the product of a matrix of emissions multipliers (μ_i) and a matrix of trade flows with each element being a bilateral trade flow (X_{ij}) between an ij pair of countries. Emissions multiplier is defined as $\mu_i \equiv e_i(\mathbf{I} - \mathbf{A})^{-1}$, i.e. by multiplying production-based emissions intensities, e_i, by the global Leontief inverse, with $\mathbf{A}$ the matrix of input coefficients from the exporter's domestic input-output table.

Following Aichele and Felbermayr (2015), we now introduce climate policy into the gravity model and decompose its effect on carbon embodied in trade into two terms: a **technique effect** corresponding to the substitution away from energy toward other factors of production and a **scale effect** reflecting the change in export volumes driven by the change in the cost of production relative to other countries. Let us assume here that the climate policy takes the form of a carbon tax (T). In a bilateral setting, the exporter's technique and scale effects are both affected by its own policy (T_i) as well as by the trading partner's (T_j). Neglecting third-country effects and denoting $\Delta z = dZ/Z$, we can linearize Eq. (2.2 as:

$$\Delta c_{ij} = \kappa_{\mu,i}\Delta t_i + \kappa_{\mu,j}\Delta t_j + \kappa_{Q,i}\Delta t_i + \kappa_{Q,j}\Delta t_j \tag{2.3}$$

with the first two terms of Eq. (2.3) corresponding to the technique effect and the last two terms to the scale effect and with the various κ denoting the elasticity of the corresponding variables with respect to the carbon tax.

When country i (the exporter) tightens its policy, while country j does not ($t_i > 0, t_j = 0$), the technique effect is negative ($\kappa_{\mu,i} < 0$) as it is more costly for firms to produce carbon-intensive goods and as a result their production declines. The scale effect is also negative ($\kappa_{Q,i} < 0$) as the increasing cost from the carbon tax deteriorates the exporter's competitiveness. Hence, we expect the carbon content of export to decline when the exporter tightens its climate policy.

When country j (the importer) tightens its policy, while country i does not ($t_j > 0, t_i = 0$), there is no technique effect as country j's climate policy does not have any price effect in country i ($\kappa_{\mu,j} = 0$), while the scale effect is positive as country i's competitiveness improves relative to country j ($\kappa_{Q,j} > 0$). Hence, we expect the carbon export content of export to increase when the importer tightens its climate policy, giving rise to a 'carbon leakage'.

2.2 Empirical model for assessing the drivers of CO_2 emissions embodied in international trade

To empirically determine the drivers of the carbon content of trade flows and test for carbon leakage, we substitute Eq. (2.1) into (2.2) and log-linearizing the equation in order to obtains an empirical gravity equation for CO_2 embodied in exports as follows:

$$lnC_{ij} = \alpha_0 + \alpha_1 lnY_i + \alpha_2 lnY_j + \alpha_3 lnD_{ij} + \alpha_4 lnT_i + \alpha_5 lnT_j + \pi_i + \pi_j + \epsilon_{ij} \tag{2.4}$$

The size of the countries (Y_i and Y_j) is measured by GDP and/or population. Alternatively, GDP per capita is also currently used in the literature. The trade costs (D_{ij}) are measured by transportation costs (usually proxied by the distance between the two countries). Climate policy (T_i and T_j) is measured by carbon taxes or environmental policy indicators. Finally, the trade barriers (Π_i and Π_j) in our theoretical model are time-invariant exporter- or importer-specific factors, captured by country-specific fixed effects (π_i and π_j).

3 Data and variables

3.1 The OECD data on CO_2 emissions embodied in international trade

The methodology used by the OECD to estimate the origins of CO2 emissions embodied in international trade and final demand (TECO2 database) is based on equations using vectors of production-based emissions and output multipliers from OECD's Inter-Country Input-Output (ICIO) tables. This accounts for the double counting issues associated with emissions embodied in intermediate trade flows e.g. exported intermediate products could be used in domestic production processes. The computation follows Eq.(2.2. More details about the estimation of emissions embodied in a specific country pair's gross trade flow are available in Yamano and Guilhoto (2020).

The indicators provided by the TECO2 database provides insights about the role played by international trade in the allocation of emissions between consumer and producer countries, revealing the degree to which they are outsourcing the production from their most polluting industries to countries who are less stringent with emissions. Overall, world CO_2 emissions from fuel combustion increased by about 19% between 2005 and 2015, from 27.1 to 32.3 Gigatonnes (Gt) i.e., an annual growth rate of 1.8%. Among the main exporters of CO_2, China accounts for 24% of total trade-embodied emissions in 2015 compared with 20% in 2005 and is followed the United States (7%), India (5%), Russia (5%) and Germany (4%). The largest importers are the world's major economies, with the United States and China absorbing together a quarter of trade CO_2 in 2015 (Cezar and Polge, 2020).

Large advanced economies are generally large importers of CO_2 as they consume more CO_2 than they produce. Conversely, emerging and commodity producing economies are net exporters of CO_2. Over the period 1995-2005, there was a reduction in net imports of CO_2 emissions by OECD countries from non-OECD economies from 2.1 to 1.6 Gt. However, CO_2 embodied in gross exports increased in most countries and regions with stronger increases in non-OECD countries. For instance, embodied emissions increased by 7% in the euro area over 1995-2005 while it increased by 32% in ASEAN countries. The increases in CO_2 embodied in exports in emerging economies are mainly explained by their development process and they remain net CO_2 exporters owing to the expansion of their manufacturing base to meet the consumption needs of more developed economies. The purpose of our empirical exercise will be to assess to what extent environment policy explains part of this worldwide configuration of CO_2 emissions embodied in trade.

3.2 Measuring environmental policy stringency

There are several approaches to the measurement of environmental policy stringency (Botta and Kózluk, 2014).The first category refers to *de jure* indicators reflecting either the signing of international agreements (single policy event) or aggregating data on national legislation regarding diverse policy instruments in order to define a measure of the overall environmental policy stance of a country. The second approach refers to *de facto* indicators reflecting mainly environmental performance or the outcomes of environmental policies.

In our empirical exercise, we will use both approaches. The *de jure* indicator will be the Environmental Policy Stringency (EPS) Index computed by the OECD and the *de facto* indicator will be the Environmental Performance Index (EPI) from the Yale Center for Environmental Law & Policy.

The OECD Environmental Policy Stringency Index (EPS) is a country-specific and internationally-comparable measure of the stringency of environmental policy. Stringency is defined as the degree to which environmental policies put an explicit or implicit price on polluting or environmentally harmful behavior (Botta and Kózluk, 2014). The index ranges from 0 (not stringent) to 6 (highest degree of stringency). The index covers 28 OECD and 6 BRICS countries for the period 1990-2015. The index is based on the degree of stringency of 14 environmental policy instruments, primarily related to climate and air pollution. The index aggregates several individual policy instruments (like taxes on pollutants), subsidizing instruments (such as feed-in tariffs or subsidies to R&D) and regulation (standards). The composite indicator of environmental policy stringency (EPS) is made of two sub-indices, one reflecting market-based policies – taxes, trading schemes, feed-in tariffs – (thereafter EPS^M) and one reflecting non-market based policies – standards and R&D subsidies – (thereafter EPS^{NM}). In our empirical evidence we will make use of both sub-indices as well as the composite one (EPS).

The Environmental Performance Index (EPI) provides a data-driven summary of the state of sustainability around the world (Wendling et al., 2020). Using 32 performance indicators across 11 issue categories, the EPI ranks 180 countries on environmental health and ecosystem vitality. These indicators provide a gauge at a national scale of how close countries are to established environmental policy targets. As the index covers a wider range of countries that the OECD EPS, including many emerging and commodity-exporting countries, it will be of particular relevance to assess the role of environmental policy in the emission embodied in trade between net exporters and net importers of CO_2. Among the issue-category indicators, the Climate Change (CCH) is particularly relevant for our study as it combines growth rates and intensity of the main greenhouse gas emissions. In our empirical exercice this index is a weighted sum of seven climate change variables (CO_2 Growth Rate (CDA), CH_4 Growth Rate(CHA), F-gas Growth Rate (FGA), N_2O Growth Rate(NDA), Black Carbon Growth Rate(BCA), Greenhouse Gas Intensity Trend (GIB), Greenhouse Gas per Capita (GHP))[1]

As our model includes relative performance between a country and its trading partner (bilateral trade flows), we will introduce these policy stringency indicators not only separately but also as dissimilarity indices by taking the difference in their values for each country pair. For instance, our EPS indicator will be transformed as $EPS_{ijt} = EPS_{it} - EPS_{jt}$, for each pair of countries i and j and each year t. We will do the same for the other indicators (EPS^M, EPS^{NM} and CCH).

Table 1 gives a first overview of the relationship between CO_2 embodied in trade and

[1] CCH=(CDA*0.56375) + (CHA*0.15375) + (FGA*0.1025) + (NDA*0.05125) + (BCA*0.05125) + (GIB*0.05125) + (GHP*0.025625), the weighs are obtained following data on https://epi.yale.edu/

	EPS_i	EPS_j	EPS_{ij}
lnC_{ij}	-0.0867	0.0855	-0.1245
$lnC_{eme,adv}$	-0.0858	0.1275	-0.1534

	CCH_i	CCH_j	CCH_{ij}
lnC_{ij}	-0.1606	0.0163	-0.1241
$lnC_{eme,adv}$	-0.3190	0.1624	-0.3526

Table 1: Pair-wise cross-section correlations

our various measures of environmental policy stringency. We compute the correlations between CO_2 embodied in exports from country i to country j and the *de jure* and *de facto* indicators in country i, in country j and with the difference between the two. We also distinguish among the pairs, exports from emerging economies from those originating from advanced economies. These pair-wise cross-section correlations shows first a negative relationship between the exports of CO_2-goods and the environmental policy of the exporting country. By contrast, such a relationship becomes positive when considering the policy index in the importing countries. In other words, a more stringent environmental policy is associated with higher exports of CO_2-intensive goods, illustrating a possible 'carbon leakage' of environmental policy through international trade. These correlations are even stronger when focusing only on the exports from emerging economies to advanced economies. Finally, the more strigent the policy of the importer compared to the exporter (implying lower EPS_{ijt} and CCH_{ijt}), higher is the correlation with CO_2 embodied in trade, illustrating again a possible phenomenon of 'carbon leakage'. We will see therefore the importance of conducting a proper econometric analysis to verify whether these simple correlations imply or not a genuine relationship once controled for usual trade determinants.

3.3 Gravity model variables

As detailed in Section 2.2, standard standard gravity model variables will be included in our empirical model. This includes GDP per capita, trade costs, common language and contiguity. To account for the propensity to emit CO_2 when producing goods, we also include energy use and electricity production in the exporting country. All data are from the World Bank database, except trade costs, which are from ESCAP-World Bank Trade Cost Database. Alternatively, we also use distances between country from the CEPII database, which also provides dummy variables for common language and contiguity.

3.4 Similarity in the production structure

In some specifications, we complement the above variables with an indicator measuring the similarity in the production structure between the exporting and importing countries. This variable, noted S_{ij}, is an index computed as follow.

$$S_{\mathrm{ij}} = \sum_{n}^{N} |s_{\mathrm{ni}} - s_{\mathrm{nj}}| \tag{3.1}$$

Where s_{ni} and s_{nj} are respectively sector n's share in total value added in country i and country j. N represents the total number of sectors[2]. We used five sectors ($N = 5$). When the origin country (i) and the destination country (j) are completely symmetric then $S_{\mathrm{ij}} = 0$; when they are completely asymetric, $S_{\mathrm{ij}} = 2$. In practice, $S_i j$ ranges between 0 and 1.20, with the mass of the distribution spreading between 0.2 and 0.5 - see Figure 1 in Appendix).

The rationale behind this inclusion is the need to reflect the sectoral differences across countries that could justify the trade of carbon-intensive goods. In particular, these emissions embodied in exports could correspond to intersectoral trade needed to provide raw materials or less sophisticated input from countries specialised in upstream sectors towards countries specialised in downstream sectors. Although our analysis remains at aggregate level, we account for the potential impact of such a sectoral dissimilarity on policy-related carbon leakage by multiplying the similarity indicator to the policy variable of the importing country. This will therefore measure whether stringent policy in importing countries could foster the import of carbon-intensive goods from country whose sectoral composition of production is different.

4 Empirical results

We present first the empirical approach chosen before presenting our main results. We complete the empirical exercise by a series of robustness checks. As our various exercises include variables whose country coverage is different, we report in Appendix the list of countries corresponding to each exercise.

[2]These sectors are (1) Total services included construction, (2) Electricity, gas, water supply, sewerage and remediation service (3) Manufacturing , (4) Mining and quarrying, (5) Agriculture, forestry and fishing

4.1 Empirical approach

Our empirical research is based on the fixed effect (FE) model as benchmark. It consists of including country fixed effect for both countries (importers and exporters). In the range of estimation methods, the FE model is widely used (Rose and Van Wincoop, 2001; Feenstra, 2004). The strength of this method comes from the fact that it provides unbiased coefficients of gravity (following previous works as in (Bacchetta et al., 2012)). We estimate our models using panels covering between 33 and 56 countries over the period 2005-2015. To gauge the robustness of our results we also estimate our gravity equations with two other estimation methods. These methods concern the standard Ordinary Least Square (OLS) and Poisson-pseudo-maximum likelihood (PPML). The pooled OLS is used here as a benchmark alternative. For panel data, the OLS estimator is more efficient than the FE estimator, while it is potentially inconsistent since it excluded unobserved fixed effects. In our exercise, the aim is simply to check whether the FE results still holds with a more efficient estimator.

The second alternative relies on the PPML approach which is particularly appropriate to deal with heteroscedasticity, model missspecification and excess zero (Prehn et al., 2016). The PPML regression finds its origin in spatial sciences where Davies and Guy (1987) recommended its use instead of the popular Poisson regression. In the international trade literature the use of the PPML took off with the paper of Silva and Tenreyro (2006). In the gravity model this approach tends to produce less bias parameter estimates. While the standard FE model will remain our benchmark estimation results, we will compare them in a robustness section with these two alternative estimation methods.

4.2 Benchmark results

We present first results related to the *de jure* measures of environment policy and present thereafter those related to *de facto* indicators.

4.2.1 Results using *de jure* policy indicator

Following the literature of gravity models, we consider models including standard variables explaining bilateral trade between countries. These include GDP per capita, trade costs and other gravity variables like common languages or contiguity. To account for the fact that we are interested by the CO_2 content of exports we include in our models not only our environmental policy indicators but also variables that could reflect the energy content of goods produced in the exporting country, like energy use or electricity production. Overall, we consider 4 different models from the simplest where we consider only GDP per capita, trade costs and environmental policy indicators to the most comprehensive one that includes all variables. Table 2 shows the results when we consider separately the EPS indicator for both the exporting and importing countries.

Before looking at the environmental policy variables, a first point worth mentioning is related to the signs and significance of GDP per capita. Unlike gravity equations used to describe trade flows, our specification shows that the CO_2 content of exports is inversely proportional to the level of development of the exporter. The richer the exporter is, the less exports contain CO_2. This result is not surprising and is related to the literature on the Environmental Kuznets Curve that predicts emissions to decline (or at least moderate) as per capital GDP increases beyond a certain threshold (see Dées, 2020, for recent evidence). If production of high-income countries are less and less intensive in CO_2, the same phenomenon should then apply to their exports as well. However, our results show that concerning imports, higher income also leads to higher imports of goods that are rich in CO_2. This result shows what we may usually call a carbon leakage, high-income country consumer bypassing environmental regulation applied to domestic production by importing from lower-income countries. However, this result should not been taken at face value as it relates only to consumer preferences and not necessary to domestic regulation. The elasticity of CO_2 embodied in exports to environmental policy variables are therefore key to bring evidence to this issue.

The results show that both EPS_i and EPS_j appear with negative and significant coefficients. The more stringent a country is on environmental policy (both for exporters and importers), the less trade flows are intensive in CO_2. On the exporter side, environmental policy restricts the production of CO_2 and therefore the country becomes less specialised in carbon-intensive goods. On the import side too, when domestic policy becomes more restrictive, we do not find any evidence of carbon leakage, as the carbon content of imports declines too.

The other variables have the expected sign and, interestingly, do not alter the results on the policy variables, showing the robustness of our findings. In all specifications, trade costs enter significantly with a negative sign, as expected. Adding energy-related variables shows that the CO_2 embodied in trade also depends positively on the energy use of the exporter as well as its electricity production.

Looking at our results into more details, we notice that the size of the coefficients of the policy variables is larger in absolute terms for the exporter's policy indicator than for the importer one. In Table 3 we replace our policy variables by a single one taking the difference in the degree of stringency between the exporting country and the importing one, giving an indication of the relative level of stringency in environmental policy between each country. Such an index of dissimilarity in policy appears with a negative sign, meaning that a country whose environmental policy is more stringent than its partner's will export goods with lower content in CO_2. Taking this results from the importer's side, it means that environmental policy actions have significantly less impact in relative terms on CO_2 intensity of imported goods. Such effect is nevertheless not significant in our estimation results. Altogether, our results show that although we do not find evidence of carbon leakage (coefficient of EPS_{ij} negative in Table 3), the virtuous countries from an environmental policy viewpoint tend to import the most from the least virtuous ones. From a policy perspective, as differences in environmental regulation across countries tends to support trade in carbon-intensive goods, this result points to the importance of international coordination and cross-country harmonization in environmental policy in order to curb CO_2 emissions embodied in trade.

To go deeper into the analysis of the role of *de jure* policy in the CO_2 content of trade, we decompose the policy indicators into market and non-market instruments. Table 4 shows the results of specifications including such a decomposition. The results found with the aggregate index are verified when breaking it down into its market and non-market components. Interestingly, the sensitivity of CO_2 embodied in exports tends to be lower for market-related measures (-0.05 for exporters and -0.03 for importers) compared with non-market ones (around -0.06). Non-market measures (regulatory measures or support to low-carbon technology) contribute therefore more to avoid trade-related carbon leakage compared to market ones (i.e. carbon tax). Moreover, when using bilateral measures, while the coefficient related to EPS^{M}_{ijt} is significantly negative (Model 5), the one related to EPS^{NM}_{ijt} is not significant, meaning that the difference between exporters and importers vanishes for non-market measures.

4.3 Results using *de facto* environmental indicators

We then run estimations using similar specifications but replacing our *de jure* policy indicators (EPS) by *de facto* measures of environmental performance related to climate change (CCH). Table 5 gives the estimation results when including both indicators related to the exporter and the importer performance. In all models both CCH_i and CCH_j appear significant with a negative sign. The results found with our *de jure* policy indicator is therefore confirmed by the estimates including *de facto* measures. Comparing the size of the coefficient is not easy as the EPS is an indicator ranging from 0 to 6, while CCH is measured as a percentage. However, if we multiply the CCH-related coefficients by a factor of 100/6, we find values that are comparable (i.e. around -0.2 for country i indicator and -0.1 for country j indicator). These results confirm therefore not only the sign but also the magnitude of the sensitivity of CO_2 embodied in trade to environmental indicators. In the case of CCH, as the indicator cover more countries than EPS, this result is moreover satisfactory since doubling the size of the sample do not change the results. As it includes many more emerging and commodity-exporting countries, this sample also appears even more relevant to assess the presence of carbon leakage behaviours.

We also consider another set of estimations replacing the environmental indicators by a bilateral one, computed as for EPS as the difference between a country index and its partner's. Table 6 shows again that when environmental performance is dissimilar across partners, the more virtuous ones tend to import more carbon-intensive goods from less environmentally efficient partners. As for the case with *de jure* indicators, this result shows that a large heterogeneity in environmental performance is detrimental to the reduction in CO_2 emissions embodied in trade.

4.4 Robustness exercises

To check whether the previous results are robust, we perform four different types of exercises. First, we replace the trade cost measure with the distance between exporters and importers, as it is usually done in the gravity model literature. Second, we run our various models using different estimation methods. Third, we account for the role of sectoral differences across trade partners to check whether the impact of our environmental policy and climate change variables still holds when we control for sectoral dissimilarity between exporters and importers. Finally, we focus on samples covering only exports from emerging economies to advanced ones, since this type of country pairs is usually described as the most subject to carbon leakage phenomena.

4.4.1 Replacing trade costs by distances

Our measure of trade costs relies on actual data on transportation costs. This allows us to account for the fact that such costs evolve over time and that decreasing trend in transportation costs may have supported trade in carbon-intensive goods, making them very competitive even when they originate from some far-off partners. In the literature, however, trade costs are usually proxied by distance between partners. In this first robustness exercise, we check whether replacing our time-varying transportation cost variable by a constant distance for each country pairs change the results on our environmental policy indicators. Table 7 show that (log) distances enter negatively into our models, as expected. At the same time, this does not dramatically modify the coefficient values of the environmental variables, making our main results robust to the choice of trade cost indicators. For instance, the coefficient associated with EPS_i is equal to -0.09 (same value in our benchmark results for Model 4) and the one associated with EPS_j is equal to -0.08 (against -0.06). Similarly, the coefficients associate with CCH_i and CCH_j are respectively -0.007 and -0.004 when using distances, while they were equal to -0.008 and -0.005 with our trade cost measure.

4.4.2 Estimation methods

We turn next to the role of the estimation methods. The models presented in the Table 8 take into account our two measures of environment policy stringency taken separately for each trade partner as well as bilateral differences. For each cell, we have computed an average of eight models. The eight models are composed of four models using the trade cost as shipping cost variable and four models using instead the distances. The results show us that the Pooled OLS method gives similar coefficients, although slightly larger in absolute value in few models. This means that the distribution around the average estimates are relatively well centered. The PPML estimates give less satisfactory results when using EPS as environmental policy indicator. The signs are correct but the impact of domestic environmental policy on CO_2 emissions embodied in exports is not significant. The impact of importers' EPS on trade remains significant but its value is about a half less. Even if the PPML is qualified to be robust in gravity analysis, its estimation in presence of high-dimensional fixed effects leads to non-convergence (see Magerman et al., 2016; Sauvé and Roy, 2016). Moreover, when using CCH as *de facto* environmental measure, the three methods all give the expected sign but only two one them are significant (CCH of importer and exporter). Overall, both Pooled OLS and PPML methods confirm the main results of our benchmark estimates and do not bring any evidence of carbon leakage as trade determinant across countries.

4.4.3 Sectoral considerations

Our next robustness exercise takes into account the role of sectoral dissimilarity across trade partners. The rationale of this robustness check is to consider whether the above results would not be biased by the fact that CO_2 emissions embodied in trade may mainly reflect the fact that the structures of production differ between exporters and importers. The fact that CO_2 intensive goods are mainly exported from emerging countries or from countries with abundant natural resources to advanced economy might bias the impact estimates of *de jure/ de facto* environmental policy measures. Using the structural similarity index described in Eq. 3.1, we account for the role of structural differences by including an interaction variable between our environmental policy indicators of the importers' countries and this bilateral similarity index. The idea is to verify if an importing country with stringent policies tend to import CO_2-intensive goods from countries whose production structure is very different. At maximum (theoretical) level of dissimilarity (when $S_ij = 2$), the coefficient associated with the interaction term should be half (in absolute value and of opposite sign) of the importer's policy indicator coefficient to point to any evidence of carbon leakage via trade with the most dissimilar countries. As seen above, the maximum value of S_ij is around 1.20 and most of the distribution ranges between 0.2 and 0.5, so that the interaction term coefficient must be at least twice as large (in absolute value) as the corresponding coefficient to cancel the negative impact of policy stringency on CO_2 emissions embodied in trade.

Table 9 report the results for both the *de jure* and the *de facto* indicators. For EPS, the interaction term does not appear as significant, indicating that the importing countries do not bypass the stringency of their domestic policy by importing from countries whose production structure is different. For CCH, however, the coefficient of CCH_jxS_{ij} is significant and its absolute value is slightly higher than the coefficient of CCH_j. In the extreme case where a country should trade only with countries that are structurally different (i.e. the few cases at the maximum value of our dissimilarity index distribution), this result would point only to a cancellation of the impact of environment performance on reducing the importing of CO_2-intensive goods. At the same time, even in this extreme case, the results still do not bring evidence of any large carbon leakage effect due to environment policy outcome. Moreover, given data availability constraints, our sectoral dissimilarity index does not cover a wide range of countries and may not be representative of dissimilarity between emerging and advanced economies. This is what we check in our last robustness exercise.

4.4.4 Trade between emerging and advanced economies

Finally, we partition our sample into pairs that correspond only to exports of CO_2-intensive goods from emerging economies to advanced countries. The list of countries covered is reported in Appendix. Table 10 with *de jure* environmental policy indicators (Emerging to Advanced Economies) shows that the *de jure* indicator does not appear significant any longer when restricting trade flows to exports from emerging to advanced economies. The other gravity variables remain significant with the same sign as in our benchmark results. Energy use continues to positively influence the CO_2 content of exports while electricity does not enter significantly into the equation. These results indicate that restricting our sample to such pairs of countries does not bring any evidence of effects of environmental policy on reductions in CO_2 emissions embodied in trade. At the same time, they do not show any evidence of carbon leakage either. It is worth noting that the sample in this case is rather small as it covers exports from 9 emerging economies to 24 advanced countries.

When including the *de facto* indicator (Table 11), the sample size is larger as it covers trade flows from 24 emerging economies to 32 advanced countries. In this exercise, our benchmark results are confirmed. However, the value of the CCH_i coefficient is much lower now (from 0.09 to 0.06 in Model 1), meaning that the impact of environmental performance on exports of CO_2-intensive goods is less in the case of emerging economies. Similarly, the CCH_j coefficient is lower (-0.06 in our benchmark results compared to -0.04 in the emerging-advanced economies trade), confirming the results reported in Table 9. When a country imports from partners that are less similar, the effects of environmental performance on the CO_2-intensity of the goods are lower. In any case, however, we do not find again any evidence of carbon leakage (the signs are in all cases negative and significant), reinforcing the main results of this paper.

5 Concluding remarks

As polices to curb carbon emissions are not implemented similarly across countries, a so-called 'carbon leakage' may offset domestic carbon reductions at the global level by redirecting CO_2-intensive production to places with less stringent environmental regulation. Although the emissions embodied in international trade account for around a quarter of total global emissions, the evidence of carbon leakages coming from environmental policies has so far been scarce and rather mixed. This article uses a standard gravity model with panel data to assess what determines the CO2 emissions embodied in gross trade flows. It pays particular attention to include, in addition to the traditional determinants of bilateral trade, measures of environmental regulation, both *de jure* (reflecting policy measures) and *de facto* (reflecting environmental performance). Our results show no evidence that environment regulation or performance would be bypassed by higher imports of CO_2-intensive goods. On the contrary, the higher the environmental performance of a country, the lower the CO_2 emissions embodied in trade. This results hold true both for the exporters and the importers. Concerning the importing countries, our results also show that even by taking into account the dissimilarity in production structure across trade partners or focusing on exports from emerging economies to advanced countries, environmental performance does not play as an incentive to offshore highly polluting activities.

Our empirical evidence also shows that the CO_2 emissions embodied in trade are rather explained by the usual determinants of international trade, such as shipping costs or income of both exporting and importing trade partners. Other traditional determinants of bilateral trade, such as common language or contiguity, also explains the trade in CO_2-intensive goods. Moreover, the energy intensity in the production of goods exported also appears as an important determinant. The dissimilarity in the production structure between the exporter and the importer tends to somewhat lower the efficiency of environment performance on CO_2 embodied in trade (evidence only with *de facto* measures) without canceling it.

Finally, the impact of domestic environment policy measures seem to be larger on exports of CO_2-intensive goods than on imports. This result point to the fact that environmental policy actions may have less impact in relative terms on imports than on production (and therefore exports). Although our results do not find evidence of carbon leakage, they still show that the virtuous countries from an environmental policy viewpoint tend to import the most from the least virtuous ones. From a policy perspective, as differences in environmental regulation across countries tends to support trade in carbon-intensive goods, this result points to the importance of international coordination and cross-country harmonization in environmental policy in order to curb CO_2 emissions embodied in trade.

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AppendixA1: Result tables

VARIABLES	Model 1	Model 2	Model 3	Model 4
logGDP_per_cap_i	-0.167***	-0.163***	-0.152***	-0.0408
	(0.0342)	(0.0342)	(0.0340)	(0.0369)
logGDP_per_cap_j	0.649***	0.653***	0.664***	0.744***
	(0.0297)	(0.0297)	(0.0295)	(0.0309)
EPSi	-0.114***	-0.114***	-0.114***	-0.0927***
	(0.0110)	(0.0110)	(0.0109)	(0.0113)
EPSj	-0.0839***	-0.0841***	-0.0840***	-0.0685***
	(0.0103)	(0.0103)	(0.0102)	(0.0101)
logTij	-1.007***	-0.961***	-0.830***	-0.889***
	(0.0707)	(0.0705)	(0.0682)	(0.0684)
Lang		0.617***	0.310***	0.303***
		(0.0790)	(0.0838)	(0.0829)
Contig			1.021***	0.982***
			(0.0894)	(0.0875)
logEnergyUse_i				1.093***
				(0.0944)
logElect_i				-0.0287
				(0.0225)
Constant	3.557***	3.074***	2.360***	-4.743***
	(0.570)	(0.567)	(0.545)	(0.853)
Observations	8,292	8,292	8,292	8,202
Number of panelid	1,056	1,056	1,056	1,056
R2	0.850	0.852	0.857	0.861

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 2: Estimations with de jure environmental policy indicators

VARIABLES	Model 1	Model 2	Model 3	Model 4
logGDP_per_cap_i	-0.277***	-0.274***	-0.262***	-0.0760**
	(0.0340)	(0.0340)	(0.0338)	(0.0366)
logGDP_per_cap_j	0.539***	0.543***	0.554***	0.680***
	(0.0298)	(0.0297)	(0.0296)	(0.0314)
EPS_ij	-0.0150	-0.0150	-0.0150	-0.00877
	(0.00927)	(0.00925)	(0.00918)	(0.00871)
logTij	-1.042***	-0.996***	-0.861***	-0.933***
	(0.0720)	(0.0718)	(0.0695)	(0.0691)
Lang		0.600***	0.301***	0.293***
		(0.0781)	(0.0831)	(0.0821)
Contig			1.003***	0.955***
			(0.0881)	(0.0860)
logEnergyUse_i				1.446***
				(0.0902)
logElect_i				-0.0768***
				(0.0234)
Constant	5.618***	5.136***	4.391***	-5.388***
	(0.585)	(0.583)	(0.563)	(0.854)
Observations	8,292	8,292	8,292	8,202
Number of panelid	1,056	1,056	1,056	1,056
R2	0.852	0.854	0.858	0.863

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 3: Estimations with de jure environment policy indicators (bilateral indices)

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5
logGDP_per_cap_i	-0.0500	-0.0656*	-0.0714*	-0.0843**	-0.0701*
	(0.0368)	(0.0364)	(0.0365)	(0.0363)	(0.0366)
logGDP_per_cap_j	0.704***	0.736***	0.677***	0.677***	0.676***
	(0.0309)	(0.0311)	(0.0316)	(0.0309)	(0.0316)
logTij	-0.905***	-0.906***	-0.933***	-0.929***	-0.933***
	(0.0688)	(0.0671)	(0.0691)	(0.0679)	(0.0691)
Lang	0.301***	0.296***	0.293***	0.292***	0.293***
	(0.0826)	(0.0826)	(0.0821)	(0.0823)	(0.0821)
Contig	0.972***	0.976***	0.955***	0.963***	0.955***
	(0.0868)	(0.0869)	(0.0859)	(0.0859)	(0.0860)
logEnergyUse_i	1.398***	0.968***	1.450***	1.442***	1.453***
	(0.0904)	(0.0980)	(0.0906)	(0.0888)	(0.0898)
logElect_i	-0.0691***	-0.00921	-0.0790***	-0.0706***	-0.0805***
	(0.0230)	(0.0232)	(0.0234)	(0.0240)	(0.0234)
EPS_MKT_i	-0.0489***				
	(0.00780)				
EPS_MKT_j	-0.0306***				
	(0.00706)				
EPS_NMKT_i		-0.0681***			
		(0.00890)			
EPS_NMKT_j		-0.0607***			
		(0.00823)			
EPS_MKT_ij			-0.00922		-0.00939*
			(0.00571)		(0.00569)
EPS_NMKT_ij				0.00114	0.00258
				(0.00676)	(0.00672)
Constant	-5.740***	-3.723***	-5.407***	-5.287***	-5.426***
	(0.851)	(0.849)	(0.854)	(0.841)	(0.852)
Observations	8,202	8,394	8,202	8,394	8,202
Number of panelid	1,056	1,056	1,056	1,056	1,056
R2	0.862	0.866	0.863	0.867	0.863

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

Table 4: Estimations with de jure environment policy indicators (market and non-market policy indices)

VARIABLES	Model 1	Model 2	Model 3	Model 4
logGDP_per_cap_i	-0.257***	-0.252***	-0.244***	-0.224***
	(0.0272)	(0.0271)	(0.0270)	(0.0291)
logGDP_per_cap_j	0.460***	0.464***	0.472***	0.514***
	(0.0253)	(0.0253)	(0.0252)	(0.0264)
CCH_i	-0.00915***	-0.00908***	-0.00896***	-0.00832***
	(0.000648)	(0.000647)	(0.000645)	(0.000670)
CCH_j	-0.00592***	-0.00585***	-0.00571***	-0.00516***
	(0.000710)	(0.000708)	(0.000706)	(0.000708)
logTij	-0.906***	-0.861***	-0.784***	-0.800***
	(0.0345)	(0.0340)	(0.0341)	(0.0344)
Lang		0.955***	0.687***	0.684***
		(0.0667)	(0.0703)	(0.0700)
Contig			1.417***	1.404***
			(0.0952)	(0.0950)
logEnergyUse_i				0.388***
				(0.0675)
logElect_i				0.00392
				(0.0197)
Constant	6.963***	6.349***	5.871***	3.291***
	(0.373)	(0.376)	(0.366)	(0.616)
Observations	29,721	29,721	29,721	28,678
Number of panelid	3,031	3,031	3,031	3,031
R2	0.840	0.846	0.852	0.853

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

Table 5: Estimations with de facto climate change indicators

VARIABLES	Model 1	Model 2	Model 3	Model 4
logGDP_per_cap_i	-0.236***	-0.231***	-0.224***	-0.166***
	(0.0274)	(0.0273)	(0.0272)	(0.0292)
logGDP_per_cap_j	0.477***	0.482***	0.490***	0.554***
	(0.0253)	(0.0253)	(0.0252)	(0.0265)
CCH_ij	-0.00156***	-0.00156***	-0.00157***	-0.00119**
	(0.000521)	(0.000520)	(0.000518)	(0.000518)
logTij	-0.863***	-0.817***	-0.737***	-0.776***
	(0.0350)	(0.0345)	(0.0344)	(0.0345)
Lang		0.974***	0.699***	0.689***
		(0.0677)	(0.0713)	(0.0706)
Contig			1.455***	1.424***
			(0.0965)	(0.0956)
logEnergyUse_i				0.689***
				(0.0665)
logElect_i				0.0469**
				(0.0210)
Constant	5.334***	4.718***	4.246***	-0.445
	(0.360)	(0.363)	(0.352)	(0.576)
Observations	29,721	29,721	29,721	28,678
Number of panelid	3,031	3,031	3,031	3,031
R2	0.835	0.842	0.848	0.851

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

Table 6: Estimations with de facto climate change indicators (bilateral index)

VARIABLES	Model 1	Model 2	Model 3	Model 4
logGDP_per_cap_i	-0.174***	-0.128***	-0.0621*	-0.0251
	(0.0274)	(0.0273)	(0.0359)	(0.0360)
logGDP_per_cap_j	0.570***	0.598***	0.724***	0.792***
	(0.0255)	(0.0256)	(0.0323)	(0.0315)
logDist_ij	-1.160***	-1.160***	-1.138***	-1.137***
	(0.0254)	(0.0254)	(0.0400)	(0.0400)
Lang	0.411***	0.412***	0.313***	0.313***
	(0.0638)	(0.0638)	(0.0818)	(0.0819)
logEnergyUse_i	0.106*	0.387***	1.069***	0.669***
	(0.0614)	(0.0584)	(0.0938)	(0.0965)
logElect_i	0.0469**	0.0846***	-0.0612***	-0.00807
	(0.0187)	(0.0198)	(0.0229)	(0.0219)
CCH_i	-0.00674***			
	(0.000639)			
CCH_j	-0.00419***			
	(0.000652)			
CCH_ij		-0.000832*		
		(0.000479)		
EPS_ij			-0.00384	
			(0.00834)	
EPSi				-0.0945***
				(0.0104)
EPSj				-0.0776***
				(0.00945)
Constant	11.01***	7.940***	2.870***	3.872***
	(0.627)	(0.578)	(0.903)	(0.906)
Observations	32,536	32,536	8,886	8,886
Number of panelid	3,115	3,115	1,056	1,056
R2	0.872	0.872	0.883	0.884

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

Table 7: Robustness with distance variable

VARIABLES	FE	OLS	PPML
EPS_i	-0.1070375***	-0.0994875***	-0.0142025
	(0.0106375)	(0.0170625)	(0.0226375)
EPS_j	-0.0825***	-0.0817***	-0.0587625***
	(0.00986875)	(0.0163625)	(0.020225)
EPS_ij	-0.0113275	-0.009065	0.0275625
	(0.008845)	(0.01321375)	(0.017275)
CCH_i	-0.0080525***	-0.0091113***	-0.0031175**
	(0.00062925)	(0.00079475)	(0.00135375)
CCH_j	-0.0050138***	-0.006715***	-0.0044713***
	(0.000674)	(0.00078163)	(0.00123188)
CCH_ij	-0.0013679***	-0.0010134	-0.0002024
	(0.00049688)	(0.00064238)	(0.000925)

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 8: Robustness check – Estimation methods

VARIABLES	Model 1	Model 2
logGDP_per_cap_i	-0.0636	-0.281***
	(0.0440)	(0.0380)
logGDP_per_cap_j	0.718***	0.481***
	(0.0347)	(0.0354)
logTij	-0.770***	-0.553***
	(0.0741)	(0.0432)
Lang	0.234**	0.518***
	(0.0990)	(0.111)
Contig	1.082***	1.264***
	(0.0973)	(0.122)
logEnergyUse_i	1.040***	0.339***
	(0.113)	(0.0903)
logElect_i	0.0424	0.0572**
	(0.0316)	(0.0271)
EPSi	-0.110***	
	(0.0134)	
EPSj	-0.0799***	
	(0.0160)	
EPS_jxS_ij	0.0427	
	(0.0520)	
CCH_i		-0.00826***
		(0.00108)
CCH_j		-0.00702***
		(0.00108)
CCH_jxS_ij		0.00768***
		(0.00174)
Constant	-4.641***	3.119***
	(0.984)	(0.792)
Observations	5,952	12,046
Number of panelid	750	1,239
R2	0.837	0.845

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

Table 9: Robustness estimations including structural similarity

VARIABLES	Model 1	Model 2	Model 3	Model 4
logGDP_per_cap_i	-0.356***	-0.353***	-0.346***	-0.257***
	(0.0542)	(0.0542)	(0.0541)	(0.0654)
logGDP_per_cap_j	0.751***	0.753***	0.761***	0.827***
	(0.0989)	(0.0989)	(0.0986)	(0.101)
EPSi	0.00728	0.00842	0.0123	0.00312
	(0.0296)	(0.0295)	(0.0292)	(0.0295)
EPSj	-0.0277	-0.0283	-0.0294	-0.0230
	(0.0242)	(0.0242)	(0.0241)	(0.0235)
logTij	-1.521***	-1.485***	-1.371***	-1.420***
	(0.140)	(0.144)	(0.154)	(0.152)
Lang		0.481***	0.463***	0.449***
		(0.157)	(0.158)	(0.156)
Contig			0.848***	0.813***
			(0.148)	(0.145)
logEnergyUse_i				0.794***
				(0.220)
logElect_i				-0.0216
				(0.0765)
Constant	4.364***			
	(1.180)			
Observations	1,752	1,752	1,752	1,698
Number of panelid	216	216	216	216
R2	0.909	0.910	0.910	0.911

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

Table 10: Estimations with de jure environmental policy indicators (Emerging to Advanced Economies)

VARIABLES	Model 1	Model 2	Model 3	Model 4
logGDP_per_cap_i	-0.266***	-0.265***	-0.260***	-0.285***
	(0.0423)	(0.0422)	(0.0421)	(0.0489)
logGDP_per_cap_j	0.569***	0.570***	0.579***	0.629***
	(0.0717)	(0.0717)	(0.0713)	(0.0730)
CCH_i	-0.00615***	-0.00614***	-0.00611***	-0.00543***
	(0.00137)	(0.00137)	(0.00136)	(0.00144)
CCH_j	-0.00383**	-0.00382**	-0.00369**	-0.00314**
	(0.00154)	(0.00154)	(0.00154)	(0.00156)
logTij	-0.875***	-0.864***	-0.799***	-0.797***
	(0.0734)	(0.0732)	(0.0765)	(0.0761)
Lang		0.755***	0.671***	0.677***
		(0.129)	(0.123)	(0.124)
Contig			1.762***	1.766***
			(0.210)	(0.209)
logEnergyUse_i				0.135
				(0.138)
logElect_i				0.0750
				(0.0518)
Constant	-0.310			
	(0.940)			
Observations	7,234	7,234	7,234	6,739
Number of panelid	737	737	737	737
R2	0.857	0.860	0.866	0.866

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

Table 11: Estimations with de facto climate change indicators (Emerging to Advanced Economies)

AppendixA2: Data sources

Variables	Sources
Environmental Policy Stringency (EPI)	Organization for Economic Co-operation and Development (OECD)
Electricity production from oil, gas and coal sources	World Development Indicators (WDI), World Bank
Energy use	World Development Indicators (WDI), World Bank
Climate Change	Yale Center for Environmental Law & Policy
CO2 emissions embodied in international trade	Organization for Economic Co-operation and Development (OECD)
Trade in Value Added	Organization for Economic Co-operation and Development (OECD)
GDP, Population	World Development Indicators (WDI), World Bank
Trade cost, Distance, Common language and Contiguity	Centre d'Études Prospectives et d'Informations Internationales (CEPII)

Table 12: Variables and their sources

AppendixA3: List of countries

- **Panels based on de jure measures (EPS) as environmental policy variable (33 countries)** : Australia, Austria, Belgium, Brazil, Canada, China (P.R.), Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Korea, Netherlands, Norway, Poland, Portugal, Russian Federation, Slovak Republic, Slovenia, South Africa, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States.
- **Panels based on de facto measures (CCH) as environmental policy variable (56 countries)** : Argentina, Australia, Austria, Belgium, Brazil, Brunei Darussalam, Bulgaria, Canada, Chile, China, Colombia, Costa Rica, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, Kazakhstan, Korea, Latvia, Lithuania, Luxembourg, Malaysia, Malta, Mexico, Netherlands, New Zealand, Norway, Peru, Philippines, Poland, Portugal, Russian Federation, Saudi Arabia, Singapore, Slovak Republic, Slovenia, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, United Kingdom, United States.
- **Panels including dissimilarity index ($S_i j$) (33 countries for the model 1 and 44 countries the model 2)** : Australia, Austria, Belgium, Brazil, Canada, Chile, China(People's Republic of), Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Russian Federation, Saudi Arabia, Slovak Republic, Slovenia, South Africa, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States
- **Panels based on exports from emerging economies to advanced economies with EPS** : Exporters: Brazil, China P.R., Hungary, India, Indonesia, Poland, Russian Federation, South Africa, Turkey; Importers: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Korea, Netherlands, Norway, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, United Kingdom, United States.
- **Panels based on exports from emerging economies to advanced economies with CCH** : Exporters: Argentina, Brazil, Brunei Darussalam, Bulgaria, Chile,

China P.R., Colombia, Costa Rica, Croatia, Hungary, India, Indonesia, Kazakhstan, Malaysia, Mexico, Peru, Philippines, Poland, Russian Federation, Saudi Arabia, South Africa, Thailand, Turkey; Importers: Australia, Austria, Belgium, Canada, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Malta, Netherlands, New Zealand, Norway, Portugal, Singapore, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, United Kingdom, United States.

AppendixA4: similarity index distribution

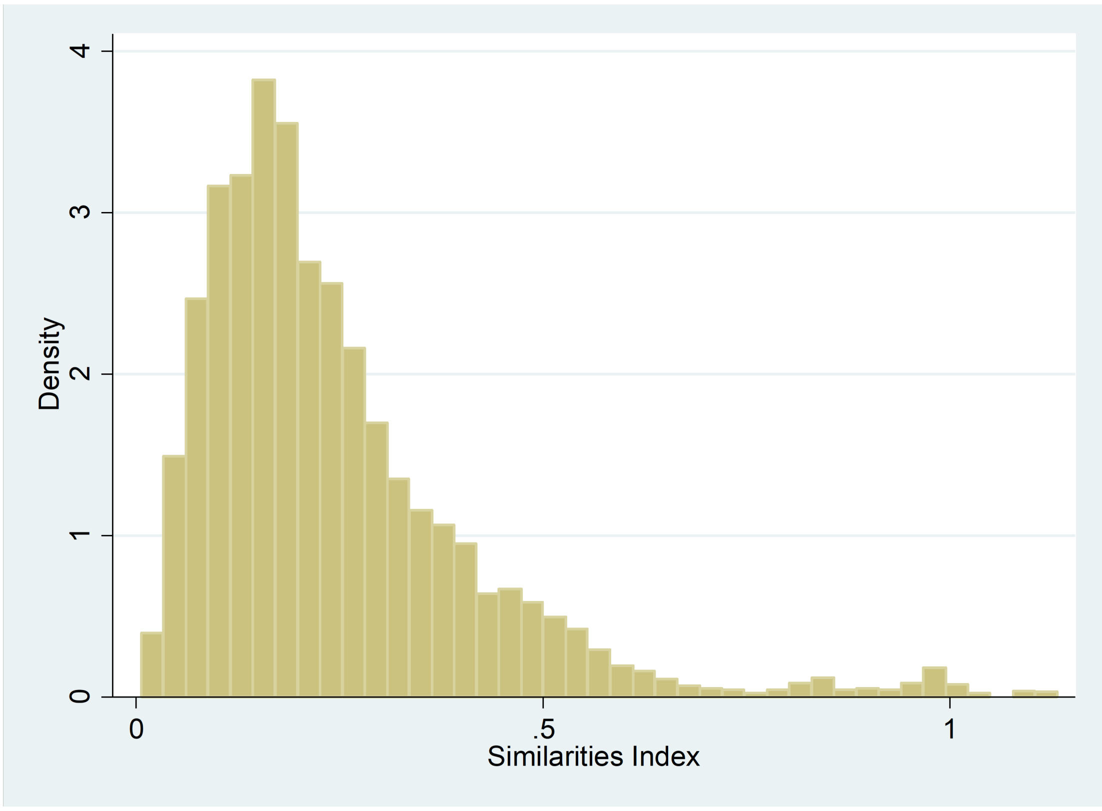

Figure 1: similarity index distribution

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