Climate Change and Trade: What Unilateral or Multilateral Actions Are Needed to Mitigate Emissions Embodied in Trade Flows

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The environmental impact of international trade is a concerning issue in the fight against climate change. Trade liberalization—combined with globally fragmented environmental policies—is often associated with emissions leakages and the formation of pollution havens because trade allows countries to outsource emissions-intensive production to countries with weaker environmental regulations. Literature on this subject has therefore suggested that a globally coordinated policy response is necessary to mitigate the impact of trade on climate change. This study aims to contribute to the existing literature by identifying unilateral and multilateral actions countries can take to mitigate the impact of embodied emissions associated with bilateral trade. Through a gravity model estimating the impact of regulation, domestic carbon intensities, and several other gravity variables, this study is able to provide novel conclusions in the context of the existing literature. Particularly, a unilateral strengthening of environmental regulation by the importing country can contribute to climate change mitigation in the best case, and has a statistically insignificant effect in the worst case. This study also finds that multilateral coordination in technological diffusion and trading agreements can also aid in mitigation efforts.

1. INTRODUCTION

International trade has often been characterized as an essential component in a country's development. According to the World Bank (2018), countries highly exposed to international trade tend to (a) experience higher growth rates and lower prices, (b) provide better incomes for their citizens, and (c) be more innovative and productive. Indeed, the worldwide trend of globalization has coincided with improving several quality of life indicators among developing countries. For instance, real incomes in developing countries have doubled over the past 20 years, whereas poverty rates among these economies have decreased by half within the same period (Wiedmann, 2016). Though international trade has yielded some benefits to those in the developing world, some academics have argued that the gains of trade have come at the cost of environmental degradation. Among the negative impacts of international trade is the potential for emissions, or carbon leakage, which is defined as the outsourcing of emissions-intensive activities from countries with stringent environmental regulations to countries with weaker environmental regulations (Lopez et al., 2018; Felbmermayr & Peterson, 2020).

The environmental impact of trade is a timely issue in the context of climate change. The total volume of traded goods and services has increased rapidly over the past several decades, being 35 times larger today than it was in the 1950s (Wiedmann, 2016). Consequently, the scale and share of emissions associated with trade have also increased. According to Peters et al. (2011), carbon emissions associated with the production of traded goods accounted for around 4.3Gt of CO_2—equivalent to 20% of global CO_2 emissions—in 1990. This figure rose to 7.8 Gt of CO_2, or 26% of global CO_2 emissions, in 2008. In relation to this, the IPCC (2018) stated that global average temperatures are currently 1.0°C higher than pre-industrial levels due to the unprecedented level of greenhouse gases emitted globally. The IPCC further projected that the average global temperature will be 1.5°C higher compared to pre-industrial levels between the years 2030 to 2052 if current trends of greenhouse gas emissions remain unchanged. Consequently, the global effects of climate change are expected to be more pronounced. In a world that is 1.5°C warmer, extreme weather events are expected to be more powerful and frequent, and biodiversity loss will be amplified—among many other potential threats (IPCC, 2018). Given these effects, the emissions-related impacts of trade on climate change may negate its positive impacts in the long run.

It is in this context that policy discussions centered around the environmental impact of international trade have gained prominence. These are usually centered around the question of how to minimize the environmental impacts of international trade or if governments should be granted the ability to link trade policy with environmental policy (Taylor, 2004). Such questions are important when considering the international and intergenerational costs of greenhouse gas emissions. The costs of greenhouse gasses—wherever or whenever they are emitted—are paid for by current and future generations wherever they may reside (Andrew, 2008; Rezai et al., 2012). Given this scenario, this study aimed to determine potential unilateral and multilateral actions that countries can pursue to reduce the impact of international trade on emissions associated with trade. This is done by empirically estimating the impact of environmental stringency, level of development proxied by Annex I membership, technology proxied by Greenhouse Gas (GHG) intensity, and trade-facilitating or trade-depressing variables on GHG flows from one country to another.

2. LITERATURE REVIEW

Carbon emissions have traditionally been monitored at a territorial level, where domestic agencies account for the level of CO2 emitted by economic activities within a nation's territory (Tukker et al., 2020). Utilizing territorial emissions data, a multitude of academic studies found that economic growth has decoupled with growth in CO2 emissions among developed economies (Handrich et al., 2015). However, a fundamental flaw in conclusions drawn from territorial-based emissions studies is that they are unable to consider the issue of emissions leakage, where countries move carbon-intensive production abroad (Jakob et al., 2014). The recognition of this phenomenon serves as the primary motivation for consumption-based accounting (CBA): a methodology where the responsibility of CO2 emissions is placed upon which country consumes a good, rather than where the good is produced (Jiborn et al., 2018; Tukker et al., 2020). To take into account fragmented production chains in modern economies, this process is usually conducted via environmentally extended multiregional input-output (EE-MRIO) analyses (Peters et al., 2012). CBA studies typically share the same conclusions: trade is a significant contributor to CO2 emissions, and that developed countries tend to be net importers of carbon, whereas developing countries tend to be net exporters of carbon (Davis & Caldeira, 2010; Peters et al., 2011; Kanemoto et al., 2014).

Although Environmentally Extended Multiregional Input Output (EE-MRIO) can provide information on the volume and direction of GHG emissions flows, EE-MRIO alone cannot provide information on the factors that affect the intensity of flows from one economy to another. As such, it is important to explore the various methodologies applied to analyze the impacts of different factors affecting GHG emissions associated with the production and consumption of traded goods. A significant number of studies dealing with GHG flows employed computable general equilibrium (CGE) modeling for ex-ante analyses in estimating the potential extent of GHG flows associated and the economic competitiveness of economies when certain environmental regulations are put in place. The majority of CGE literature conclude that asymmetric environmental policies could potentially lead to emissions leakages, as implementing stronger environmental regulations could potentially harm the competitiveness of environmentally stringent countries and encourage offshoring of pollutive industries to less environmentally stringent nations (Babiker, 2005; Mattoo et al., 2009; Elliott et al., 2010). However, some studies contradict these findings. For instance, Grossman and Kreuger (1991) claimed that trade could reduce GHG emissions through improved technology. Additionally, Baylis et al. (2014) claimed that stricter environmental regulation actually reduces global GHG emissions through the *abatement resource effect*.

Although there is a wealth of ex-ante analyses on the impact of trade on emissions, relatively little ex-post analyses have been made on the issue (Kumar & Prabkahar, 2016). Nonetheless, much of the ex-post analyses utilize two distinct methodologies to estimate the determinants of GHG flows. The first set of papers involve extending EE-MRIO with structural decomposition analysis (SDA). Studies utilizing this methodology conclude that economic growth, population growth, and differences in production costs, rather than the implementation of stronger environmental regulations, are the prime determinants of an increase in the volume of GHG emissions associated with the production of traded goods (Arto & Dietzenbacher, 2014; Hoekstra et al., 2016). The second strand of ex-post measurements on the environmental impact of trade involves the construction of gravity models, which carry diverging conclusions. Sato and Dechezleprêtre (2015) showed that a unilateral strengthening of environmental regulations has a neutral effect on GHG flows. Meanwhile, Kumar and Prabkahar (2016) showed that a unilateral strengthening of environmental regulations by the importer reduces the volume of GHG emissions associated with a country's imports. Lastly, Duarte et al. (2018) and Ben-David et al. (2020) showed that countries offshore pollutive activities when they unilaterally strengthen their own environmental regulations.

The literature overall appears to be divided on the impact of trade on the environment. An existing gap in the literature, particularly in the ex-post level of analysis, is that country-level studies do not take into account the relative strength of trading partners' environmental regulations. Most studies in this field tend to assume that countries enact similar sets of policies or assume that a country has stringent policies when it is a signatory to the Kyoto Protocol. These analyses may fail to take into account that some countries may be more stringent than others or can enforce policies more consistently than others. In other words, the mere existence of a policy is not enough for a thorough analysis because the execution of these policies is also an important factor. As such, this study aims to contribute to the existing literature by extending Ben-David et al.'s (2020) manner of analysis to the country-level by estimating the impact of the relative strength of two trading partners' environmental regulations on the emissions embodied on their trade.

3. FRAMEWORK

Decomposition on the Environmental Impact of Trade

Grossman and Krueger (1991) provided important insights on the environmental impact of trade. Specifically, they decomposed the impact of trade into three spheres: (a) the scale effect, (b) the composition effect, and (c) the technique effect. The scale effect captures the effect of trade in a manner by which trade leads to economic activity and subsequently increases greenhouse gas emissions. The composition effect refers to specialization in either clean or dirty goods, which may either decrease or increase greenhouse gas emissions. Lastly, the technique effect refers to the ability of trade to lower the greenhouse gas intensity of nations through technical diffusion.

Pollution Haven Hypothesis

The pollution haven hypothesis, as outlined by Copeland and Taylor (2004), assumes the existence of two types of countries: (a) countries with strong environmental regulations and (b) countries with weak environmental regulations. Also, two types of goods are assumed: (a) less emissions-intensive or clean goods, and (b) emissions-intensive or pollutive goods. Under these circumstances, it is assumed that countries with strong environmental regulations will specialize in carbon-efficient goods, particularly due to penalties and strict regulations that prevent firms in these countries from emitting pollutants upon the environment. In contrast, firms with weak environmental regulations tend to specialize in carbon-intensive goods. As expounded by Copeland and Taylor (2004), specialization in carbon-intensive goods occurs due to two reasons. First, firms from environmentally stringent countries outsource their production to less environmentally stringent countries to escape high costs associated with complying with stringent environmental regulations. Second, the lack of environmental regulations encourages local entrepreneurs to set up pollutive industries in the country.

Discussions on the pollution haven hypothesis tend to center around carbon leakages from developed to developing countries. In essence, developed countries are simply assumed to have stronger environmental regulations, whereas developing countries have weaker environmental regulations (Chichilnisky, 1994). Such a theoretical framework adequately explains why conclusions in studies conducted by Davis and Caldeira (2010), Peters et al. (2011), and Malik and Lan (2016) tended to show that developed countries are net importers of CO_2 emissions, whereas developing countries are net exporters of CO_2 emissions. Differences in environmental regulations encourage the outsourcing of carbon-intensive production from developed states to developing countries. Additionally, the high volume of carbon emissions embodied in the developing countries' exports would naturally outweigh the low volume of carbon emissions embodied in developed countries' exports to developing countries.

Comparative Environmental Advantage

The concept of comparative environmental advantage, as outlined by Lopez et al. (2018) and Nielsen and Kander (2020), explains that emissions savings can be accrued in international trade if countries exploit differentials in emissions intensities in trade per sector. For instance, if country A can produce good 1 while emitting less CO_2 emissions per unit produced compared to country B, and if country B can produce good 2 while emitting less CO_2 emissions per unit produced relative to A, then specializing in their respective comparative carbon advantage will lead to emissions savings in trade. Consistent with the domestic technology assumption methodology outlined by Arto et al. (2014) and Lopez et al. (2018), emission intensities are proxies for a country's technological state. Particularly, a lower emissions intensity implies that a country utilizes more carbon-efficient technology.

Comparative environmental advantage explains how differences in technology can generate emissions savings when countries participate in international trade, as importing from more efficient trading partners allows global emissions savings. Conversely, it also explains how trade can generate emission gains, in that if countries import from carbon inefficient countries relative to their own domestic industries, there will be higher CO_2 emissions compared to an environment without trade. Comparative environmental advantage provides nuance on the use of the domestic technology assumption as a means of introducing how much emissions a country would avoid if it produced its own goods and services domestically.

Gravity Model

The gravity model is often used in international economics to estimate the various determinants of trade. It is inspired by Newton's law of gravity, whereby countries are more likely to trade with one another. The larger the "economic mass" of a country—often proxied by GDP—and are less likely to trade, the farther they are from one another (Shepherd, 2016). Typically, intuitive gravity models take trade flows from an exporting country to an importing country as the regressand. Additionally, the GDP of both importer and exporter, along with distance, are typically included as regressors. However, most gravity models now include other factors that facilitate trade, such as a shared official language and shared colonial history (Shepherd, 2016).

This study draws heavy inspiration from the intuitive gravity model, though it incorporates findings from previous studies to determine the "economic mass" of two trading partners, as well as pertinent trading costs. Studies have shown that wealth, proxied by GDP per capita, and population are shown to have caused increases in GHG flows (Arto & Dietzenbacher, 2014; Hoekstra et al., 2016; Malik & Lan, 2016). As such, this study assumes that both GDP per capita and population can sufficiently embody the concept of economic mass in the intuitive gravity model. Furthermore, this study takes inspiration from Duarte et al.'s (2018) and Ben-David et al.'s (2020) econometric measures that control for distance, colonial history, common membership in an RTA, and common language.

4. METHODOLOGY

This study analyzed trends on the flow of emissions of Kyoto GHGs associated with the trade of an exporting country to an importing country. The samples include data across 144 economies arranged into 19,980 unique pairs from 2007 to 2015. However, there are gaps in 2010, 2011, and 2014 due to missing data on the stringency and enforcement of environmental regulations indices published by the World Economic Forum. Several factors were identified as determinants of GHG flows from an exporting country to an importing country, particularly: (a) difference in stringency and enforcement of environmental regulations of the importing and exporting country, (b) GHG intensities of importing and exporting countries, (c) type of party to the UNFCCC of importer and exporter, (d) shared membership in RTAs, (e) GDP and GDP per capita, (f) population, (g) distance, (h) a common official language, and (i) a shared colonial history. A glossary of the variables is shown in Table 1.

Table 1

Summary of Variables Used in This Study

Variable	Label
Embodied Kyoto GHG emissions in Kt CO2 equivalent from exporter (i) to importer (j)	GHG_{ij}
Difference in stringency and enforcement of environmental regulations index between importer (j) and exporter (i)	$SEERdiff_{ji}$
Natural logarithm of GHG intensity, measured in Kt CO2 equivalent over billion GDP in current prices	lnGHGPerGDP
GDP per capita	lnGDPC
Both importer and exporter are Annex I parties	BothAnnex
Only exporter is Annex I party	OnlyAnnexOrig
Only importer is Annex I party	OnlyAnnexDest
Common RTA	RTA
Population	lnPop
Distance	ldist
Common language	Comlang
Colonial history	Colony
Interaction between colonial history and distance	Colony ∗ lnDist

Source: Author

This study utilizes the stringency and enforcement of environmental regulations (SEER) index developed by Ben-David et al. (2020) to measure the strength of a country's environmental regulations. The SEER index essentially merges the stringency of environmental regulations and the enforcement of environmental regulations of the World Economic Forum's Travel and Tourism Competitiveness Report. The value of SEER is computed as shown in Equation 1, whereby the product of both the stringency and enforcement indices is divided by the maximum score of 7.

$$SEER = \frac{1}{7}\,(SER * EER) \quad (1)$$

Additionally, the relative strength of two trading partners' environmental regulations are measured by estimating $SEERdiff_{ij}$, or the relative strength of the importer's SEER index compared to that of the exporter. As shown in Equation 2, $SEER_j$ denotes the SEER index of the importer j, while $SEER_i$ indicates the SEER index of the exporter i. It should be noted that a positive SEERdiff value implies the importer has stronger environmental regulations relative to the exporter, while a negative SEERdiff value implies the exporter has stronger environmental regulations relative to the importer.

$$SEERdiff_{ji} = SEER_j - SEER_i \quad (2)$$

To determine the impacts of these determinants, this study utilized a gravity model estimated via Poisson pseudo maximum likelihood (PPML). The model utilized in this study is shown in Equation 3 and is applied to all observations in this study.

$$\begin{aligned} GHG_{ij} = {} & \beta_1 + \beta_2(SEERdiff_{ji}) + \beta_3(lnGHGPerGDP_i) + \\ & \beta_4(lnGHGPerGDP_j) + \beta_5(lnGDPC_i) + \beta_6(lnGDPC_j) + \\ & \beta_7(BothAnnex) + \beta_8(OnlyAnnexOrig) + \\ & \beta_9(OnlyAnnexDest) + \beta_{10}(RTA) + \beta_{11}(lnDist) + \\ & \beta_{12}(lnPop_i) + \beta_{13}(lnPop_j) + \beta_{14}(Comlang) + \\ & \beta_{15}(Colony) + \beta_{16}(Colony * lnDist) + \epsilon \end{aligned} \quad (3)$$

Furthermore, the samples were divided into four groups to provide more insights as to the differing trends between developing economies (non-Annex I parties to UNFCCC), and developed economies (Annex I parties to UNFCCC). These groups are: (a) trade between developed countries, (b) trade between developing countries, (c) trading relationships where the developing country is the exporter, and (d) trading relationships where the developed country is the exporter. Equation 4 is utilized in the groupwise analysis, which is a modification of Equation 3 that excludes the Annex I variables due to the nature of the disaggregation.

$$\mathrm{GHG_{ij}} = \beta_1 + \beta_2(\mathrm{SEERdiff_{ji}}) + \beta_3(\mathrm{lnGHGPerGDP_i}) + \beta_4(\mathrm{lnGHGPerGDP_j}) + \beta_5(\mathrm{lnGDPC_i}) + \beta_6(\mathrm{lnGDPC_j}) + \beta_7(\mathrm{RTA}) + \beta_8(\mathrm{lnDist}) + \beta_9(\mathrm{lnPop_i}) + \beta_{10}(\mathrm{lnPop_j}) + \beta_{11}(\mathrm{Comlang}) + \beta_{12}(\mathrm{Colony}) + \beta_{13}(\mathrm{Colony} * \mathrm{lnDist}) + \epsilon \quad (4)$$

Finally this study utilizes the method suggested by Halvorsen and Palmquist (1980) and Thornton and Innes (1989) in interpreting the rate of change on a logged dependent variable due to a unit increase of independent variables not expressed in their natural logarithms. Generally, this method is expressed in Equation 5. $\Delta\%Y$ represents the percent change in the dependent variable given a unit-increase in a dummy variable or through a unit-increase in a parameter expressed in levels. Meanwhile, β_n= Estimate of a coefficient associated with a 1-unit increase in a dummy variable or through a unit increase in a parameter expressed in levels.

$$\Delta\%Y = \left(e^{\beta_n} - 1\right) * 100 \quad (5)$$

Thornton and Innes (1989) recommended using this correction because multiplying the coefficients gathered from regression analyses by 100 (or $\beta_n * 100$) to estimate the rate of change becomes more inaccurate the larger the value of β_n. Such methods in interpreting coefficients have been utilized in similar studies, particularly Ben-David et al. (2020), who utilized Equation 5 in interpreting SEER and dummy variables included in their study.

5. RESULTS AND DISCUSSION

The regression analyses show no evidence that importers are offshoring emissions-intensive production when they unilaterally strengthen their environmental regulations. On the contrary, a unilateral strengthening of environmental regulations can reduce the volume of GHG flows by 8.66%. However, there appears to be evidence that developing nations—or non-Annex I countries—are specializing in emissions-intensive exports. Meanwhile, developed nations—or Annex I parties to the UNFCCC—are specializing in relatively cleaner exports. This is shown from the findings that trading relationships where the Annex I country are exporters tend to be associated with lesser GHG emissions on average, relative to trading relationships where non-Annex I countries are exporters. In the disaggregated analysis, a unilateral strengthening of an importer's environmental regulations has no statistically significant impact on the GHG emissions embodied within a non-Annex I country's exports. This could indicate that, in a worst-case scenario, a unilateral strengthening of environmental regulations does not promote emissions leakages. This is because producers may be passing on higher costs associated with more stringent environmental regulations onto domestic consumers (Sato & Dechezleprêtre, 2015).

The impact of technology, as proxied by a country's GHG intensity, appears to be substantial. On average, a 1% increase in an exporter's GHG intensity is associated with a 1.3% increase in the volume of GHG emissions embodied in the country's exports. In the disaggregated analysis, the GHG intensities of Annex I importers tend to have a statistically significant positive impact on GHG emissions embodied on their imports. Although no literature has explained this effect, one may infer that developed countries utilizing emissions-intensive techniques of production are likely to import pollutive inputs from emissions-intensive sectors. On the other hand, the GHG intensity in trade between non-Annex I countries is negatively correlated. This may indicate that non-Annex I countries are exploiting their partners' comparative environmental advantage by offshoring pollutive activities to more efficient partners. The groupwise analyses also show that the magnitude of the impact of GHG intensities in a non-Annex I exporter's embodied emissions is generally larger than that of Annex I exporters.

Table 2

Global Trade Gravity Estimates Using GHG Emissions Embodied in Exports as Dependent

Variable	$\mathrm{GHG_{ij}}$
Difference in stringency and enforcement of environmental regulations between importer and exporter	-0.0906*** *(0.02679)*
Natural log of GHG intensity (exporter)	1.3054*** *(0.1050)*
Natural log of GHG intensity (importer)	0.1250 *(0.1169)*
Natural log of GDP per capita (exporter)	1.1000*** *(0.0437)*
Natural log of GDP per capita (importer)	1.2001*** *(0.0718)*
Natural log of population (exporter)	0.9817*** *(0.0295)*
Natural log of population (importer)	0.9320*** *(0.0263)*
Both countries are Annex I parties to the UNFCCC	-0.7633*** *(0.2060)*
Only exporter is an Annex I party	-0.3257 *(0.1010)*
Only importer is an Annex I party	-0.1951 *(0.1843)*
Common signatories to a tegional trading agreement	0.5784*** *(0.1169)*
Natural log of distance between importer and exporter	-0.6103*** *(0.0398)*
Common official language between importer and exporter	0.4312*** *(0.1525)*
Colonial history between Importer and exporter	3.0391*** *(0.8873)*

Interaction between colonial history and distance	-0.3515*** *(0.1116)*
Constant	-52.6899*** *(2.3842)*
R-squared	0.7587
RESET (p-value)	0.2148

Note: Robust standard errors in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1
Source: Author's calculations

Table 3

Trade Gravity Estimates in Trade Between Countries of the Same UNFCCC Party Status Using GHG Emissions Embodied in Exports as Dependent

Variable	Trade Between Annex I Countries	Trade Between non-Annex I Countries
Difference in stringency and enforcement of environmental regulations between importer and exporter	-0.1035*** *(0.0283)*	-0.0481 *(0.0433)*
Natural log of GHG intensity (exporter)	1.0040*** *(0.1069)*	1.4821*** *(0.2007)*
Natural log of GHG intensity (importer)	0.2048** *(0.1009)*	-0.3439** *(0.1485)*
Natural log of GDP per capita (exporter)	0.8112*** *(0.1125)*	1.2231*** *(0.0754)*
Natural log of GDP per capita (importer)	1.0465*** *(0.1330)*	0.8942*** *(0.0637)*
Natural log of population (exporter)	0.8703*** *(0.0324)*	0.9827*** *(0.0412)*
Natural log of population (importer)	0.9213*** *(0.0288)*	0.8430*** *(0.0439)*
Common signatories to a regional trading agreement	0.3797*** *(0.0769)*	0.5102*** *(0.1580)*
Natural log of distance between importer and exporter	-0.5779*** *(0.0356)*	-0.7279*** *(0.0904)*
Common official language between importer and exporter	0.2688*** *(0.0950)*	0.6715*** *(0.2052)*
Colonial history between importer and exporter	3.6283*** *(0.6843)*	
Interaction between colonial history and distance	-0.4377*** *(0.0875)*	
Constant	-45.4138*** *(2.3972)*	-46.6057*** *(2.2409)*
R-squared	0.8595	0.6494
RESET (p-value)	0.9284	0.9453
Observations	8,816	46,980

Note: Robust standard errors in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1
Source: Author's calculations

Estimates on the impact of gravity variables appear to be in line with much of the trade gravity literature. The results show that larger GHG flows are to be expected when nations are wealthier and more populous, as richer and more populous nations are more likely to trade with one another. (Shepherd, 2016). Additionally, distance appears to be associated with lesser GHG flows as this implies greater trade costs between two trading partners. Trade-facilitating factors, such as sharing a common official language, colonial linkages, and common membership in a regional trading agreement, appear to have a positive impact on GHG flows. Though, as a policy variable, extra attention is needed towards the formation of RTAs. This is because when both importing and exporting countries are members in at least one RTA, the volume of GHG emissions is—on average—expected to be 78.32% higher compared to trading relationships where both nations are not signatories of at least one RTA.

Table 4

Trade Gravity Estimates in Trade Between Countries of Different UNFCCC Party Status Using GHG Emissions Embodied in Exports as Dependent

Variable	Annex I as Exporter, Non-Annex I as Importer	Annex I as Importer, Non-Annex I as Exporter
Difference in stringency and enforcement of environmental regulations between importer and exporter	-0.0807** (0.0386)	-0.0040 (0.0256)
Natural log of GHG intensity (exporter)	1.0445*** (0.1334)	1.4178*** (0.1435)
Natural log of GHG intensity (importer)	0.1277 (0.1350)	0.3910*** (0.1379)
Natural log of GDP per capita (exporter)	1.1220*** (0.1285)	1.1325*** (0.0542)
Natural log of GDP per capita (importer)	1.1257*** (0.0549)	1.4509*** (0.1608)
Natural log of population (exporter)	0.8644*** (0.0327)	1.0078*** (0.0192)
Natural log of population (importer)	0.8859*** (0.0368)	1.0259*** (0.0207)
Common signatories to a regional trading agreement	0.3378*** (0.1611)	0.4596*** (0.1263)
Natural log of distance between importer and exporter	-0.7326*** (0.0812)	-0.4936*** (0.1278)
Common official language between importer and exporter	0.5466** (0.2295)	0.0104 (0.1455)
Colonial history between importer and exporter	-1.2070 (1.3579)	1.1271 (2.1376)
Interaction between colonial history and distance	0.1917 (0.1589)	-0.0567 (0.2451)
Constant	-46.8919*** (2.3763)	-61.5527*** (1.7010)
R-squared	0.8078	0.9258
RESET (p-value)	0.6625	0.8319
Observations	20,691	20,691

Note: Robust standard errors in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1
Source: Author's calculations

6. CONCLUSION

Trade has undoubtedly benefited much of the world. However, the environmental impact of trade could potentially erase these gains in the future, especially amidst the ongoing climate crisis. As such, mitigating the volume of emissions released in the production of traded goods and services is an essential component in the fight against climate change. In this light, this study attempted to estimate the impacts of several variables that potentially affect the volume of GHG emissions embodied in trade flows to determine potential unilateral and multilateral policy actions that may help mitigate the environmental impact of trade. Based on the results, governments and multilateral bodies may opt to pursue three forms of policies to reduce the environmental impact of trade.

Unilaterally Strengthening Environmental Regulations

In the absence of a multilaterally coordinated strengthening of environmental regulations, countries can unilaterally strengthen their own environmental regulations to mitigate their impact on climate change without fear of emissions leakages. These policies may include ending fossil fuel subsidies, implementing carbon taxes, or implementing stronger environmental standards. As the study's results show, environmental regulations can reduce GHG emissions embodied in their imports at a global level. However, this trend may differ among developed or developing countries. In trading relationships where developing countries are exporters, a unilateral strengthening of environmental regulations by the importer shows little empirical evidence of increasing or decreasing emissions embodied in their partner's imports. However, when developed countries are exporters, a unilateral strengthening of environmental regulations by the importer can reduce the volume of emissions associated with their partner's imports.

Increase Adoption and Rate of Technical Diffusion of Low-Carbon Technologies

There is a need to improve the technologies utilized in both exporting and importing nations to become less emissions-intensive. This is because adopting greener technologies reduces the volume of emissions associated with the production of exports and reduces the need to import pollutive inputs. Special attention should be granted in trade relationships where the developing country is an exporter. This is because the magnitude of the impact of GHG intensities in the volume of GHG emissions associated with the exports of developing countries is generally larger than that of developed countries. This policy recommendation can be actualized by increasing domestic adoption and increasing rates of technical diffusion of low-carbon technologies (LCTs) across developed and developing countries. These LCTs include products such as electric vehicles, solar photovoltaics, and wind turbines.

Pigato et al. (2020) cited potential avenues by which countries can unilaterally and multilaterally increase the adoption of LCTs. Firstly, national governments can introduce demand-pull policies to foster the market for LCTs through policies like subsidies and green public procurement programs. Secondly, national governments can increase their country's ability to absorb and adopt LCTs by strengthening their human capital, physical infrastructure, and financial markets. Thirdly, countries may multilaterally pursue processes by which international institutions can make LCT patents available to developing countries. Lastly, countries can reduce barriers that hinder trade and foreign direct investments on LCTs through trade and investment agreements.

Adopting Environmental Provisions in RTAs

Regional trade agreements are shown to have a significant effect on increasing GHG emissions embodied in trade. These environmental provisions can come in many forms, such as (a) improvements in environmental protection, (b) adoption of environmental laws, (c) harmonization of environmental laws, and (d) promotion of trade in LCTs (Monteiro, 2016). For instance, the establishment of the East African Community's Common Market called for the highest number of provisions related to the harmonization of environmental regulations. In this agreement, parties agreed upon developing common environmental regulations, incentives, and standards. Additionally, the RTA signed between the EU, Colombia, and Peru explicitly called for the removal of trade and investment barriers that hindered innovation, development, and deployment of technologies that can contribute to climate change mitigation and adaptation.

Indeed, empirical evidence shows that environmental provisions can reduce GHG emissions. In a study by Baghdadi et al. (2013), emissions per capita of trading pairs covered by environmental provisions are lower by 18% relative to countries part of RTAs without environmental provisions. Additionally, Brandi et al. (2020) also showed that adopting environmental provisions in RTAs is likely to reduce the volume of pollutive exports from developing countries and shift their export production towards cleaner goods. These stylized facts highlight the role RTAs can play in mitigating the impact of trade.

Furthermore, future research in this field may choose to tackle the following limitations of this study to improve the quality of analysis on the flow of GHG emissions embodied in trade.

7. LIMITATIONS

Tackle the Monetary Unit Assumption

Firstly, the analysis of this study is limited by the monetary unit assumption, given that MRIO databases' emissions data will be based on monetary flows multiplied by the GHG intensities from one country to another. As such, the figures used in the regression analyses of this study cannot account for price differences in exports and imports (Arto et al., 2014). The practical implication of such a limitation is that the level of emissions associated with a single product priced at \$10 would be the same as 10 products priced at \$1 each. Future research on this subject could attempt to take price differences into account, either by using absolute trade volumes or adjusting for price differences to generate more accurate estimations of emissions embodied in trade.

Use an Index that Considers Differences in the Types of Environmental Policies

Secondly, although the SEER measure can be a good proxy to measure the relative strength of environmental regulations between different countries, it cannot take into account the different forms of environmental policies implemented by different countries. Introducing the effects of different environmental policies may provide valuable insights in future research.

Disaggregate Analysis Based on Sectors

Lastly, emissions data in this study are aggregated figures based on all sectors found in the Eora dataset. A disaggregated analysis per sector may provide more specific insights on how to deal with embodied emissions associated with the trade from one country's sector to another country's sector. This is because gravity estimates per sector may be different because of different emissions intensities and different inputs required to produce each sector's products.

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