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Growth potential for CO_2 emissions transfer by tariff reduction

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Abstract

A reduction in tariff barriers facilitates the relocation of factories to countries with less stringent environmental regulations. There has been rapid growth in the transfer of emissions from developing to developed countries through international trade over the last 30 years. However, almost all countries still maintain their tariff barriers, and these tariffs limit the potential to increase carbon dioxide (CO_2) emissions transfers. This paper aims to examine the impact of tariff reduction on the CO_2 embodiment associated with the imports of the group of twenty (G20) countries. The econometric analysis uses disaggregated tariff data and CO_2 embodied emissions data from 1990 to 2013. The findings reveal that a 1% tariff cut by G20 countries for mining gas, manufactured machinery, metal, and other mining imports would result in 2779, 1747, 1453, and 1018 tons of CO_2 emissions, respectively. We show that a tariff cut would increase the embodied CO_2 emissions significantly for most of the manufacturing and mining sectors. Here, we find there is a 3.5%–232.2% growth potential of CO_2 emissions embodied in imports, depending on whether G20 countries abolish tariff barriers. This scenario makes it difficult to achieve national emissions reduction targets and to implement national environmental policy.

1. Introduction

International trade develops the mechanisms to efficiently allocate resources and has played a significant role in economic development (Feenstra 2015). However, the benefit of trade is not without cost, including the uniform cost of externalities. Tradable goods may be produced in regions with poor environmental performance and protection, which has guided many studies on pollution embodied in international trade, for instance, air pollution (Kanemoto *et al* 2014, Moran and Kanemoto 2016, Zhang *et al* 2017), carbon emissions (Chen and Chen 2011, Su and Ang 2014, 2015), energy use (Chen and Wu 2017, Chen *et al* 2018), water pollution (Feng *et al* 2011, Lenzen *et al* 2013a), land contamination (Weinzettel *et al* 2013), biodiversity threats (Lenzen *et al* 2012, Kitzes *et al* 2017, Moran and Kanemoto 2017, Verones *et al* 2017) and a general review of pollutants (Wiedmann and Lenzen 2018). These studies have highlighted the magnitude of the pollution embodied in trade for countries or small groups of countries and the importance of policy to limit the emissions.

There has been concern over the increase in global climate change over the last two decades. Policy reforms to reduce the emissions of carbon dioxide (CO_2)—a factor responsible for global warming—are being discussed within the international community. Some important policy instruments such as tariffs, tradable permits, and regulatory attempts have been considered to reduce CO_2 emissions (Hoeller and Wallin 1991). The magnitude of CO_2 emissions is directly guided by international trade, which has grown faster than the growth rate of gross domestic product (GDP) (Peters *et al* 2011). If environmental policies do not account for the emissions embodied in imports, global emissions are likely to rise (Kanemoto *et al* 2014).

National and international economic policies have often ignored the environment and assumed economic liberalization. The tariff policies in the general agreement on tariffs and trade and the North American free trade agreement remain a concern for the environment (Arrow *et al* 1995). In addition, the mega regional agreement trans-pacific partnership and the transatlantic trade and investment partnership are ongoing. These trade liberalization actions can alter the success of environmental agreements.

Recent studies (Davis and Caldeira 2010, Peters *et al* 2011, Su and Ang 2011, Wiebe *et al* 2012, Su *et al* 2013) have used the input–output analysis (IOA) to identify the impact of trade on the emissions embodied because of its capability to account different countries and emissions. Trade reforms have taken place mainly via reduction of tariffs (Caliendo *et al* 2015). This leads to an increase in the size of the polluting economy and the causes of environmental degradation. Therefore, open trade policies are more pollution intensive than inward trade policies (Rock 1996). However, many economists have long argued that trade reform is not the root cause of environmental damage (Birdsall and Wheeler 1993) and some research (Cherniwchan 2017) suggest that trade liberalization reduce the emissions. It is assumed that trade reform has environmental externality in a positive or negative form.

The first United Nations Conference on Trade and Development (UNCTAD), held in 1964, proposed that developed countries should provide preferential tariff treatment for imports of manufacturing products originating from developing countries—known as the Generalized System of Preferences (GSP). However, the benefit of GSP is limited. Under the World Trade Organization (WTO) agreements, countries cannot normally discriminate between their trading partners. If a country that is a member of the WTO grants special favor in terms of a lower tariff, then it would have to extend the same to all other trading countries. The uniform tariff rate is applicable to all exporters under most-favored nation (MFN) tariffs. MFN tariff cuts would cover a broader range of products and would benefit countries excluded and included in GSP (Baldwin and Murray 1977). Tariff reform would have a profound impact on the economy and environment in many ways. Environmental economists wonder how they would impact the emissions embodied in trade.

In the post-Kyoto period, some considerable major climate policies such as economic equity, trade flexibility, optimal economic costs, and environmental effectiveness have been considered as climate policy (Aldy *et al* 2003, Bodansky 2004). However, very few environmental proposals have assessed whether international trade may be underlying some of the concerns with the Kyoto Protocol. Recently, international trade has been considered as a way to enforce climate policy (Aldy *et al* 2001), and there is increasing interest in using trade-based mechanisms such as border-tax adjustments (Ismer and Neuhoff 2004, Cendra 2006, Pauwelyn 2007). The impact of trade on the environment varies depending on the pollutant and the country. For instance, trade is found to benefit the environment in OECD countries (Managi *et al* 2009). Islam *et al* (2016) find that trade openness increases embodied emissions in international trade. Modern economies have recognized the importance of trade and it certainly benefits climate policy.

The question of how to link the extensive margin of tariff reform for individual economy with welfare remains. It is unknown if tariff reform would increase the embodied GHG by a large amount or if tariff reform would benefit the environment due to the comparative advantage in the global market. Furthermore, it is unknown how much growth of CO_2 emissions a transfer tariff reduction would induce. This issue is critical for policy makers. If tariff reform causes a significant increase in GHG, then it would be environmentally inefficient and unacceptable. Therefore, tariff reform policy should take a close look at future environmental impacts.

We focus on the impacts of tariff reduction on the import embodied CO_2 emissions of the G20, the group of 20 leading economies. This research identifies the impact of tariff reduction by the G20 countries on the import embodied CO_2 emissions in manufacturing- food, textile, paper, chemicals, metal, machinery and mining- gas, metal ore, and other mining sectors. It also predicts the growth potential of CO_2 emissions embodied in imports, depending on whether G20 countries abolish tariff barriers. According to the World Growth Indicators, the G20 economies account for 80% of global trade. Trading between the Organization for Economic Co-operation and Development (OECD) (hereafter referred to as 'developed countries') and G20 countries accounts for 80% of global energy use and CO_2 emissions (International Energy Agency 2016). The G20 economies will contribute to an 84% increase in the global energy demand between 2005 and 2030 (International Energy Agency 2006). Compared to other economies, in the G20 countries, the CO_2 emission levels are relatively high (International Energy Agency 2011).

We intended to capture the effect of tariff reduction on emissions embodied in imports of G20 countries. The demonstrate our approach, we (1) identify the impact of the trading sectors' tariffs reduction on the CO_2 embodied emissions; (2) quantify the effect of the GDP of the G20 countries, as well as that of the importing partner countries on the embodied CO_2 emissions; and (3) explore how the distance of trading partners affects embodied CO_2 emissions.

The remainder of the paper is organized as follows: in section 2, we discuss the empirical methodology we considered and the efficiency and productivity of the estimation models. Data used in the study are described in section 3, and results are presented in section 4. Section 5 includes some concluding remarks.

2. Methodology

The econometric estimations are performed by applying the two prominent panel data models: fixed effects and random effects models. These models, by virtue of their capacity to account for intertemporal, as well as individual differences, provide better control for the influence of missing or unobserved variables (Gemayel 2004). Let us consider the following simple panel data model:

$$Y_{it} = \alpha_0 + \alpha_i X_{it} + \gamma_i + u_{it}, \quad (1)$$

where,

Y_{it}	Is the dependent variable observed for country *i* at time *t*; in our case, it is the CO_2 embodied emissions, in tons.
α_0	Is the intercept
X_{it}	Is a vector of explanatory variables for country *i* at time *t*.
α_i	Is a vector of coefficients.
γ_i	Denotes unobserved target country specific effects, which are assumed to be fixed over time and vary across country *i*.
u_{it}	Is the error term.

The difference in the fixed effects and random effects models can be ascribed to assumptions as to the relationship between X_{it} and γ_i. The fixed effects approach assumes that γ_i is treated as nonrandom and hence makes the correlation between the observed explanatory variables (X_{it}) and γ_i possible. However, the random effects approach is applicable under the assumption that γ_i is random and not correlated with X_{it} and puts it into the error term (Wooldridge 2010). We determine the multicollinearity among the variables and choose the variables for the individual sector analysis.

The gravity equation is consistently used to explain different types of flows, for instance, trade, migration, commuting, and tourism (Bergstrand 1985). In our empirical analysis, we consider an adaptable regression model, based on the popular gravity model of international trade, with which we control sector specific tariff rates. In the empirical equation, we examine the impacting international trade factors on CO_2 emissions. The gravity model of trade considers the trade volume as a positive function of the 'mass' of two economies and the negative function of the 'geographic distance' between the countries. The gravity model of trade is

$$Trade_{ij} = f\frac{(\mathrm{GDP}_i \times \mathrm{GDP}_j)}{Distance_{ij}}. \quad (2)$$

The regression equation is commonly specified as

$$Trade_{ij} = a_0 + a_1(\mathrm{GDP}_i \times \mathrm{GDP}_j) + a_2(Distance_{ij}) + u_{ij}. \quad (3)$$

Embodied emissions in international trade are driven by the size of the economy of importing and exporting countries and impeded by the geographic distance of the countries. The joint effect of distance and importer also guide the embodied emissions. Most importantly, the tariff rate of the trading goods is likely to impact the embodied emissions with imports. These considerations suggest the gravity equation for environmental embodied emissions:

$$CO_2\ embodied\ emissions\ from\ import_{ijt} = \alpha_0 + \alpha_1 Tariff_{ijt} + \alpha_2(\mathrm{GDP}_{it} \times \mathrm{GDP}_{jt}) + \alpha_3 Distance_{ij} + \alpha_4(Distance_{ij} \times Area_i) + u_{ijt}, \quad (4)$$

where $u_{ijt} = \varepsilon_{ijt} + v_{ijt}$

To determine the environmental quality, we consider embodied CO_2 emissions. The dependent variable CO_2 *embodied emissions*$_{it}$ is the CO_2 footprint of a product. It considers the emissions by the total processes associated with consumption. GDP_{it} and GDP_{jt} are the input of the importers and exporters GDP at time *t*, respectively. $Distance_{ij}$ is the geographic distance between the importing and exporting countries. This variable is a proxy for the transportation cost of the trade. $Distance_{ij} \times Area_i$ is an interactive variable, which is used to identify the joint impact of distance and the land area of the importer on the embodied CO_2 emissions. u_{ijt} is an error term, consisting of an individual country effect ε_{ijt} and v_{ijt}, an idiosyncratic measurement error. u_{ijt} represents the omitted impact of other causes.

In this model, the effect of tariff policy on environmental quality is captured by the use of the MFN applied weighted mean of tariff rates. The MFN tariff rates are weighted by the import shares of the product groups for each of these countries. For the hypothesis, we expect to have a negative relationship between overall tariff rate and embodied emissions in international trade. Higher tariff rates cause imported goods to be more costly to the domestic market, and reduce their demand and hence, emissions. The United Nations Statistical Division constructs international standard industrial classifications of all economic activities (United Nations: Statistical Division 2008), and we use the classification for the consistency of industries globally.

We also considered the impact of emission intensity on the environmental embodied emission. In an extended gravity equation for embodied emissions model, we include an explanatory variable 'emission intensity' along with the equation (4). We incorporate the domestic emission intensity in our analysis to identify the carbon leakage effect on embodied emissions due to international trade.

3. Data

The analysis uses the disaggregated tariff and embodied CO_2 emissions data for panel regression from 1990 to 2013. Embodied CO_2 emissions from imports of the G20 countries and MFN *ad valorem* tariff rates related to bilateral trade are used to conduct econometric analyses. In addition, the GDP, and distance between the trading countries is also considered. We identify the impact of the economy and geographic location on embodied CO_2 emissions, related to imports.

Table 1. Description of trading sectors.

Importing country name		Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, South Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, United Kingdom, United States
Industry code	ISIC code	Industry detail
Manufacturing	[3]	Manufacturing
Food	[31]	Manufacture of food, beverages and tobacco
Textile	[32]	Textile, wearing apparel and leather industries
Paper	[34]	Manufacture of paper and paper products, printing and publishing
Chemicals	[35]	Manufacture of chemicals, petroleum, coal, rubber and plastic
Metal	[37]	Basic metal industries
Machinery	[38]	Manufacture of fabricated metal products, machinery and equipment
Mining	[2]	Mining and quarrying
Gas	[22]	Crude petroleum and natural gas production
Metal ore	[23]	Metal ore mining
Other Mining	[29]	Other mining
Year		1990–2013

Calculating the embodied emissions becomes complex due to the need to enumerate the unique production systems in individual countries to a reasonable level of sector detail and to then link these to consumption systems through international trade data. The most common methodology for this type of analysis is a generalization of environmental IOA to a multiregional setting (Lenzen *et al* 2004). Imports of one country are related to production technologies from different regions of the world. The exporting economy also delivers import demands to other countries simultaneously. Thus, embodied import factors depend on the supply chain in the interindustry demands. Therefore, different regions need to be considered for the supply path in the model. A multiregion input–output (MRIO) model can truly determine and distinguish the intermediate and final demand during trade (Wiedmann *et al* 2007). We use the Eora MRIO table (Lenzen *et al* 2012, Lenzen *et al* 2013b) as a data source for some of the dependent and independent variables. The Eora MRIO table includes 187 countries, and each country has between 26 and 501 sectors, for a total 15909 sectors. We follow Kanemoto *et al* (2012) to decompose production-based emissions into consumption-based emissions and embodied emissions in export and import, using the following equation:

$$\underbrace{F_j^s}_{\text{production}} = \sum\nolimits_r f_i^r \left[\underbrace{\sum_{it} L_{ij}^{rt} y_j^{ts}}_{\text{consumption}} - \underbrace{\sum_{it \neq s} L_{ij}^{rt} y_j^{ts}}_{\text{imports}} + \underbrace{\sum_{it \neq t} L_{ij}^{rs} y_j^{st}}_{\text{exports}} \right], \quad (5)$$

where f is factor intensities (i.e. carbon emissions divided by gross output), L is the Leontief inverse, y is final demand, and i and j are sector origin and destination. The exports term covers the factor use in region r required to produce final goods in s, which are then sold by s to t; the imports term covers factor use in region r required to produce final goods in t, which are then sold by t to s.

We begin with the TRAINS data on bilateral trade from the United Nation Statistical division. We define manufacturing sectors as ISIC trade code 3 and mining sectors as ISIC trade code 2. By observing the major import network of G20 countries, we consider the embodied emission of imports. With the bilateral trade matrix, we netted out the trade within G20 and the abovementioned regions. Every trading group except China and Russia, contains multiple countries, which are in the same geographic location.

Tariff data are obtained from the United Nation Conference on Trade and Development (UNCTAD) TRAINS database and completed when necessary from the WTO database. We obtain the UNCTAD TRAINS weighted tariff rate data, which is the average of the MFN tariff rates weighted by the product import shares corresponding to each partner country. We aggregate the MFN tariff to the 2 digit ISIC Revision 2 level by taking the weighted average of tariff lines within each ISIC code. Table 1 describes the importing countries and industries, which are taken into account.

In figure 1, it is clear that the overall MFN tariff in the manufacturing and mining sectors are gradually decreasing over the period from 1990 to 2013. Globally, imposed tariffs on the manufacturing sector are approximately 5%–10% higher than the tariffs on mining sectors.

Figure 2 represents the overall sectoral changes in MFN tariffs between 1990 and 2013. We consider CO_2 embodied emissions from manufacturing and mining sectors in our econometric analysis. Statistically, some measures of tariff reform are positively correlated, while other measures are negatively correlated with embodied CO_2 emissions.

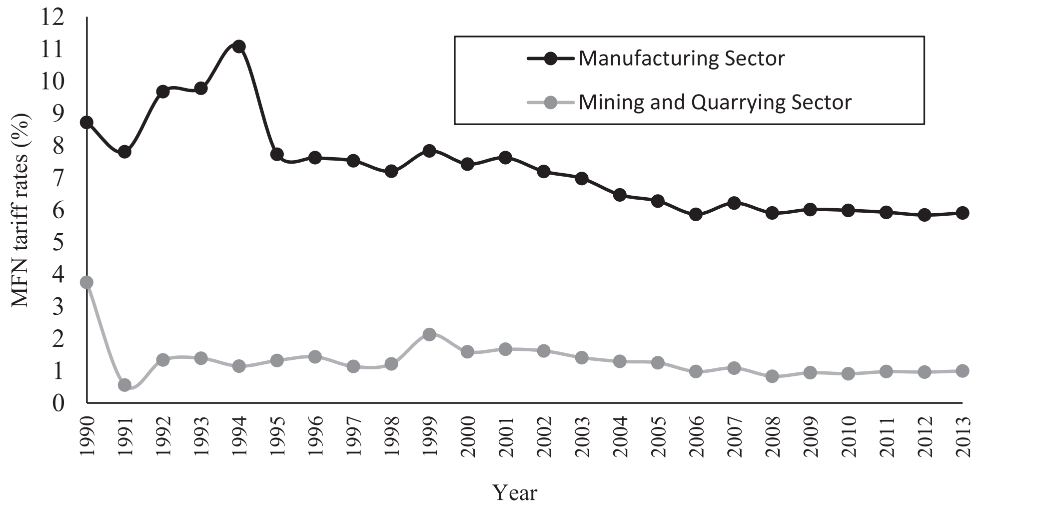

Figure 1. Average MFN tariff rates for the manufacturing sector and mining sector. Note: averages are taken over 2 digit ISIC revision 2 level good, from 1990 to 2013.

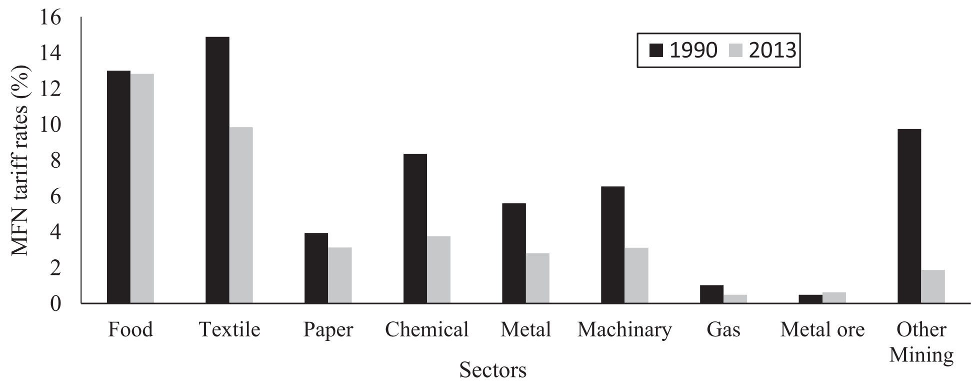

Figure 2. MFN tariff rates on manufacturing sectors and mining sectors, from 1990 to 2013.

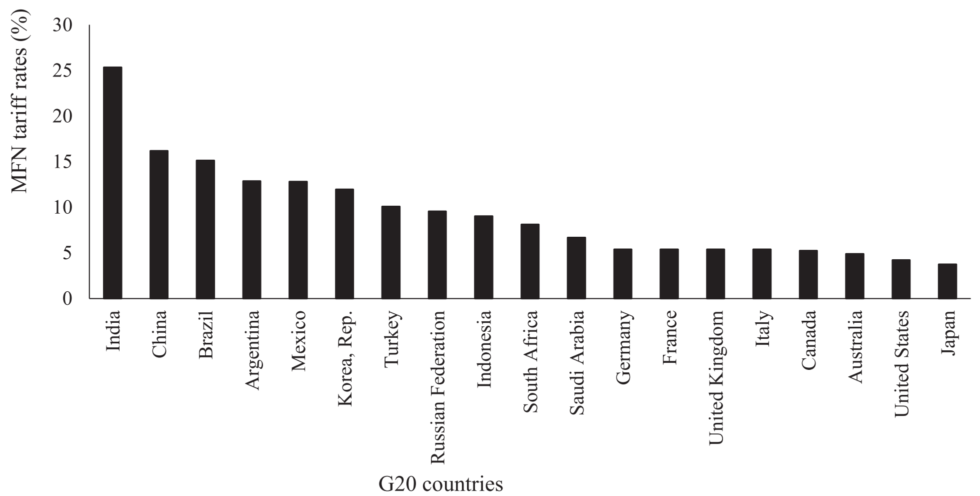

Figure 3. MFN tariff rates (%), average of all products from 1990 to 2016 (source: World Development Indicators).

Figure 3 shows the imposed average MFN tariff rates of G20 countries over the period of 1990 to 2016. India imposed the highest MFN tariff among the G20 countries and Japan had the lowest MFN tariff rate. BRIC group nations, which consist of Brazil, Russia, India and China, haven imposed relatively higher MFN tariffs to protect their growing economies.

We used the GEODIST database (Mayer & Zignago 2011), which provides a 'square' gravity dataset for all world pairs of countries, for the period from 1948 to 2015[4]. It includes the harmonized data for the country distance and area. GDP data were obtained from the World Bank Development Indicators (WDI) (World Bank 2018).

4. Results

The embodied CO_2 emissions in international trade are the sum of the direct and indirect CO_2 emissions. To identify the impact of trade liberalization on CO_2 emissions, we focus on the trading relationship of G20 countries. Our estimates using equation (2) are shown in tables 2 and 3 for manufacturing and mining sectors, simultaneously. The empirical results identify the impact of MFN tariffs on embodied CO_2 emissions from manufacturing and mining sector trade. Our gravity model of embodied emissions allows us to identify the impact of the GDP of the trading partners on embodied CO_2 emissions. We also note the impact of the distance between trading countries and the geographic area factors on CO_2 embodied emissions.

Tables 2 and 3 show the account of CO_2 embodied emissions due to the imports of G20 countries. In the following analysis, the statistically significant negative sign indicates that further trade liberalization by tariff cuts can increase the CO_2 embodied emissions for the sectors. In contrast, the statistically significant and positive sign of the coefficients shows that a tariff cut can benefit G20 countries by reducing the embodied CO_2 emissions from the sector. Our empirical analysis examines the environmental impact of increasing trade between G20 and other trading partner countries.

From 1990 to 2013, the embodied CO_2 emissions of G20 countries have increased for the MFN tariff reductions in food, textile, paper, chemical, metal, machinery, gas, and other mining sectors. The relationship is statistically significant at least at the 1% level. Intensive cross border economic integration has brought strong economic development to developed countries and G20 nations. However, environmental damages are also visible due to extensive production and trade. Among the manufacturing sectors in our analysis, machinery, metal, paper, textile, food and chemical sectors are identified as the top to bottom contributors to embodied the CO_2 emissions of G20 imports.

Food is an important sector in terms of household consumption. G20 economies generally import food, beverages and tobacco from different countries. The production of food for human consumption, particularly by industrialized agricultural practices, causes significant embodied emissions of CO_2. A 1% reduction of the imposed tariffs would guide to surplus the embodied CO_2 emissions by 308.6 tons for food manufacturing. These can occur directly or indirectly as a result of increased import. In addition, the production process, the transport, processing, packaging, marketing, sales, purchasing and cooking of food contribute to embodied CO_2 emissions. Emissions of CO_2 are also associated with meat and dairy production. The processing of ready meat and dairy products are energy intensive and increase CO_2 embodiment.

The textile industry is a source of CO_2 emissions for the imports of G20 countries from other countries. It is evident that textile sectors show significantly high environmental impacts due to the increase of imports in that sector. Both G20 countries and developed countries import textile products from each other. A 1% reduction in the imposed tariffs would serve to increase the embodied CO_2 emissions by 371.1 tons for textile manufacturing. Natural and synthetic fiber are two main type of inputs in textile manufacturing. The synthetic type of fiber production process is more CO_2 emissions-friendly than natural fiber production (Ecotextile 2011). In a liberalized trading condition, the additional demand of textile products would stimulate the production of synthetic fiber more than scarce natural fiber. As a result, the embodied CO_2 emission would increase significantly.

The paper manufacturing sector and chemical sector are also known as energy intensive CO_2 emitting industries. A 1% reduction in the imposed tariffs would guide to surplus the embodied CO_2 emissions by 388.3 tons for paper manufacturing. Similarly, a 1% reduction would serve to increase the embodied CO_2 emissions by 205.5 tons for chemical manufacturing. Machinery and metal manufacturing industries potentially increase emissions. The tariff cut would boost the embodied emissions in international trade in these sectors. For instance, in the case of imports by G20 countries, a 1% tariff cut would increase the embodied CO_2 emissions of the manufacturing machinery and metal sectors by 1747 tons and 1453 tons, respectively. Taking embodied carbon into account, the tariff reduction process truly increases CO_2 embodiment.

The mining sector generates CO_2 emissions in different stages of production. For instance, the CO_2 emissions of minerals are associated with extraction, transportation and comminution. The combined effect of multiple emission-friendly mechanisms to access final mining products makes this sector CO_2 emissions-intensive. According to our results, a 1% tariff cut for the mining sector would uplift emissions by 2779 tons for gas mining and 1018 tons for other mining sectors. Embodied emissions from G20 imports for the gas mining sector would have the greatest increase due to tariff reduction.

From 1990 to 2013, the CO_2 emissions embodied in G20 imports were largely affected by the manufacturing machinery sector. We further focus on the tariff structure of G20 countries in figure 4 and identify that they

[4] Available at CEPII, http://www.cepii.fr/.

Table 2. Impact of MFN tariffs on embodied CO_2 emissions for the import of manufacturing goods by G20 countries.

	CO_2 embodied emissions (Tons) from manufacturing sector											
VARIABLES	Food		Textile		Paper		Chemical		Metal		Machinery	
	Fe	Re	Fe	Re	Fe	Re	Fe	Re	Fe	Re	Fe	Re
Tariff (%)	-324.0^{***}	-308.6^{***}	-376.5^{***}	-371.1^{***}	-390.3^{***}	-388.3^{***}	-211.8^{***}	-205.5^{***}	-1484^{***}	-1453^{***}	-1807^{***}	-1747^{***}
	(51.84)	(51.69)	(56.38)	(56.34)	(49.82)	(49.76)	(24.05)	(24.06)	(230.1)	(228.2)	(205.8)	(205.0)
$GDP_i \times GDP_j$ (trillions)	105.4^{***}	113.4^{***}	70.59^{***}	71.37^{***}	30.74^{***}	36.21^{***}	35.68^{***}	37.08^{***}	592.9^{***}	557.5^{***}	564.9^{***}	531.8^{***}
	(18.65)	(18.35)	(15.22)	(15.10)	(8.973)	(8.817)	(4.911)	(4.856)	(50.26)	(47.96)	(49.94)	(47.68)
$Distance_{ij}$ (thousand km)		$-4{,}152^{**}$		−2759		-1910^{**}		-1180^{**}		−4109		−4033
		(1772)		(2189)		(825.0)		(536.1)		(2905)		(2836)
$Distance_{ij} \times Area_i$		0.896^{***}		0.619^{***}		0.387^{***}		0.216^{***}		0.911^{***}		0.947^{***}
		(0.162)		(0.200)		(0.0753)		(0.0489)		(0.265)		(0.259)
Constant	$56\,105^{***}$	$58\,509^{***}$	$33\,420^{***}$	$35\,104^{**}$	$24\,260^{***}$	$25\,887^{***}$	$12\,540^{***}$	$14\,695^{***}$	$41\,838^{***}$	$46\,929^{**}$	$46\,479^{***}$	$49\,411^{**}$
	(1055)	(13 723)	(1021)	(16 907)	(440.3)	(6378)	(254.7)	(4144)	(2355)	(22 524)	(2431)	(21 992)
Observations	2252	2252	2260	2260	2252	2252	2266	2266	2256	2256	2265	2265
R squared	0.21	0.23	0.12	0.14	0.10	0.23	0.10	0.16	0.10	0.11	0.10	0.10
Country fixed effect	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Hausman test	11.96^{***}		5.64^{*}		12.85^{***}		15.47^{***}		6.58^{**}		18.98^{***}	

Note: standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.
Fe and Re represent fixed effects and random effects model respectively.

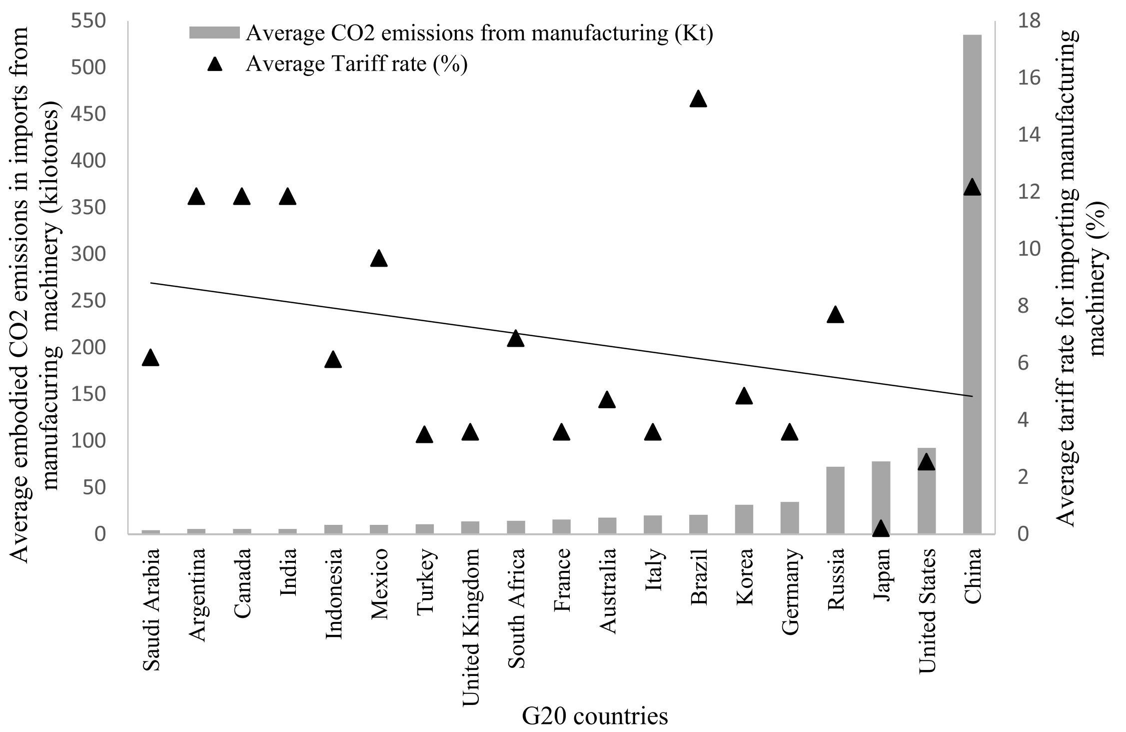

Figure 4. Average minimum imposed tariff rate on manufacturing machinery products by G20 countries and embodied CO_2 emissions for imports from 1990 to 2013.

Table 3. Impact of MFN tariffs on embodied CO_2 emissions for the import of mining goods by G20 countries.

	CO_2 embodied emissions (Tons) from mining sector					
	Gas		Metal ore		Other mining	
VARIABLES	Fe	Re	Re	Re	Fe	Re
Tariff (%)	-2868^{***}	-2779^{***}	-64.01	-60.64	-1078^{***}	-1018^{***}
	(352.5)	(351.8)	(118.6)	(118.5)	(90.41)	(89.80)
$GDP_i \times GDP_j$ (trillions)	526.3^{***}	530.0^{***}	155.7^{***}	151.5^{***}	141.3^{***}	132.7^{***}
	(43.64)	(42.75)	(12.16)	(12.07)	(12.29)	(11.80)
$Distance_{ij}$ (thousand km)		-6267		-1305^{*}		-1363^{*}
		(3880)		(759.6)		(721.7)
$Distance_{ij} \times Area_i$		1.387^{***}		0.360^{***}		0.367^{***}
		(0.355)		(0.0684)		(0.0658)
Constant	$70\,040^{***}$	$75\,585^{**}$	$11\,542^{***}$	9715^{*}	$13\,633^{***}$	$13\,271^{**}$
	(2052)	(29 515)	(2731)	(5826)	(546.8)	(5592)
Observations	1872	1872	2150	2150	2187	2187
R squared	0.12	0.18	0.20	0.21	0.14	0.16
Country fixed effect	Yes	No	No	No	Yes	No
Hausman test	7.88^{**}		4.19		21.52^{***}	

Note: standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.
Fe and Re represent fixed effects and random effects model respectively.

have imposed different levels of tariffs on manufacturing machinery imports from other countries. Japan is the lowest tariff-imposing country in manufacturing machinery and India imposes the highest tariffs in this sector. Irrespective of their tariff-imposing rate, these countries are producing approximately equal amount of embodied CO_2 emissions. In addition, the USA imposes moderate tariffs on machinery imports and produces almost equal levels of CO_2 to Japan and India. However, the moderate tariff-imposing countries, for instance, Turkey, Canada, Australia, United Kingdom, France, Italy, Germany, Korea, Indonesia, and South Africa produce moderate levels of embodied CO_2 emissions. Saudi Arabia, Mexico and Brazil impose high tariffs on manufacturing machinery imports and have low-CO_2 embodiments. Regardless of its tariff-imposing policy, China is the most CO_2 producing country in the world, which is embodied by its manufacturing machinery imports.

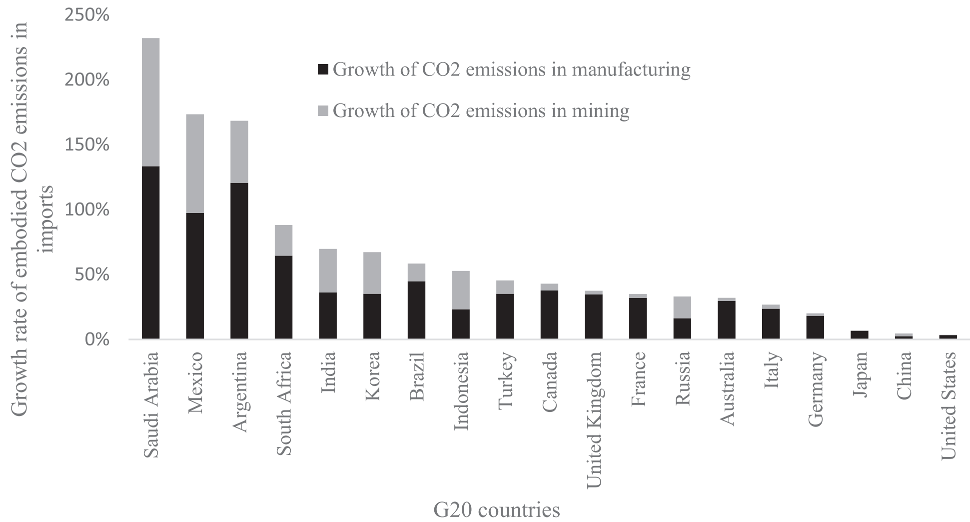

Figure 5. Growth rate scenario of the embodied CO_2 emissions in imports under the free trade condition.

The amount of CO_2 embodied in imports of manufactured and mining goods for these countries is also determined by the size of the economy and by its distance and area. We identified that the embodied CO_2 emissions in international trade have a positive relationship with the GDP size of the importing and exporting countries. GDP is an indicator of economic development and infrastructure. The capacity of manufacturing products and purchasing capability of the imports can be reflected by GDP. The higher the GDP, the greater the potential of demand and supply of tradable goods. Therefore, the more developed the trading partners, the more the embodied CO_2 emissions originate from imports. The effect of $GDP_i \times GDP_j$ is found to be positive and statistically significant, which is consistent with the prediction of the gravity model.

The distance between two trading countries is a good proxy for accessibility and transportation cost. An increase in transportation cost will increase the unit price of the goods and will also reduce the demand. The longer the distance is, the lower the accessibility of tradeable goods, and the embodied emissions are intuitive. Therefore, we expect negative coefficients for the distance variable. Our regression result shows that $Distance_{ij}$ is negatively effected by embodied CO_2 emissions for food, paper, chemical manufacturing and metal ore and other mining sectors.

The interaction between area and distance is considered to capture the joint effect of geographic characteristics of the trading countries. The $Distance_{ij} \times Area_i$ variable can identify the impact of the size of importing countries on embodied CO_2 emissions, when the distance of the exporters remains the same. Overall, we notice a positive coefficient of this variable in our analysis, which ensures that while countries import from partners at a similar geographic distance, countries with larger areas potentially produce more embodied CO_2 emissions than a comparatively smaller country.

We predict the scenario of the embodied CO_2 emissions in a tariff free condition. If the developed countries abolish their tariff, the embodied CO_2 emissions in imports would increase by 3.5%–42.9%, depending on the country. In figure 5, the growth rate of embodied emissions under the zero tariff conditions is represented for the manufacturing and mining industries. Under a zero tariff condition, the embodied CO_2 emissions in imports for developed and BRICS[5] countries would increase by 32 084 tons and 72 307 tons, respectively. In addition, Saudi Arabia, Argentina, Mexico, Turkey, Korea and Indonesia would increase their total CO_2 embodiment in imports by 66 905 tons in a free trade environment. Individually, India, Brazil, Argentina and China would have an increase of 31 867, 12 510, 12 117 and 11 685 tons of embodied CO_2 emissions in imports, respectively, if they abolish the present tariff barriers on import.

Davis and Caldeira (2010) noted that in many of the less developed countries, a large share of imported emissions is embodied in manufactured food products. Our results identify that manufactured food imports by G20 countries from developed and developing countries would uplift a large amount of CO_2 embodiment (for details please see supplementary materials is available online at stacks.iop.org/ERL/14/024011/mmedia). Tariff reductions for the manufacturing food sector would increase embodied CO_2 emissions. The textile sector, one of the major manufacturing sectors in developing countries, would produce higher embodied CO_2 emissions, due to tariff cuts. Paper manufactured in developed countries would increase embodied emissions by tariff reduction. Manufacturing chemicals would yield a high level of CO_2 emissions as a result of tariff reduction.

[5] Brazil, Russia, India, China and South Africa.

A country may be a net emissions importer without ever having to be a net emissions exporter. CO_2 emitting industries close down in a tightened environment-regulating country (A) and migrate to a country with lower environmental regulations (B). Therefore, the consumer demand of country A is met by increased production in country B, through international trade. As a result, carbon leakages take place in country B, and country A becomes a net emissions importer. Tariff reform policy makers need to consider this carbon leakage protection mechanism during tariff adjustments.

Now, we compare the impact of tariff reduction on the imports of G20 countries from developed and developing countries on a CO_2 emissions point (for details please see the supplementary materials). Our analysis focuses on two sets of trading conditions: (1) the imports of G20 countries from developed countries and (2) the imports of G20 countries from developing countries. Questions remain as to how they would respond under the condition of trade liberalization. Furthermore, it is unknown what the difference would be between CO_2 emissions due to imports from developed and developing countries under a tariff reduction situation. We note that the overall impact of tariff cuts on embodied CO_2 emissions is similar for developed and less developed countries. However, the magnitude of the impact is significantly different. If we consider the emissions from manufacturing sectors, then we notice that the tariff reduction for developed countries results in a greater increase of emissions than for tariff reduction in less developed countries. Alternatively, in the gas mining sector, tariff reductions in less developed countries create more emissions than tariff reductions in developed countries.

According to our results, tariff cuts in manufacturing and mining sectors would create a surplus of CO_2 embodied emissions in G20 countries. To quantify the actual effects of tariff changes, we use detailed tariff information and focus on both high and low income economic zones. The results are directly related to emission control policy of G20 economies, when we note that the global trading system is moving toward a zero tariff condition. Furthermore, G20 countries, developed countries, developing countries and trading zones of the world in general are continuously negotiating to reduce MFN tariffs.

We also noticed that changes in CO_2 emissions embodied in imports for G20 countries is effected by the emission intensity of the G20 countries (for details please see the supplementary materials). Overall the emission intensity of the G20 counties has a negative impact on the embodied emissions in import. Which justify that if there is tight environmental regulation in a G20 country, she has intensive to import from a pollution haven. However, this import will increase the embodied emissions in import. This finding is aligned with our intuition of the carbon leakages.

5. Conclusion and policy implications

This paper investigated possible relations between the imposition of MFN tariff reductions and the level of emissions due to G20 imports. It is evident that tariff reallocation significantly affects the account of a country's embodied CO_2 emissions. This paper also quantifies the role of GDP and distance of trading economies in embodied CO_2 emissions. We rely on a fairly long panel of data on CO_2 embodied emissions to identify the incidence of tariff cuts on the environment.

The empirical results of our paper are three-fold. First, the tariffs imposed by G20 countries significantly guide the CO_2 embodied emissions of the countries, and based upon the trading sectors, the tariffs can improve the account of CO_2 embodiment. Second, the GDP of the G20 countries, as well as that of the importing partner countries, significantly impacts embodied CO_2 emissions. Finally, the distance of trading partners inversely affects embodied CO_2 emissions. Additionally, when the distance between trading countries is the same, a geographically large country has higher CO_2 embodied emissions than a relatively small country.

Tariff reform is a popular tool for international trade and the economic welfare of countries. Incorporating the environmental impacts for trade liberalization by tariff reduction presents significant challenges for policy makers. MFN tariff reduction provides more favorable access and benefits to unlimited trade volumes. The question remains as to how policy makers would notice the impact of tariff reduction on embodied CO_2 emissions. The analysis identifies the impact of tariff reduction on the embodiment of CO_2 in imports from manufacturing and mining sectors. The findings would guide policy makers to understand the impact of tariff cuts or zero tariff conditions on embodied emissions.

In the case of the imports of G20 countries, sector specific tariff adjustments help to lead sectors to a low-CO_2 path. Essentially, the reduction of tariffs in manufacturing and mining sectors would deteriorate the success of reducing embodied CO_2 emissions in imports. In this study, we quantified embodied CO_2 associated with international trade, which would shed light on the opportunities and preferences for implementing tariff policies. This analysis is based on the best available and disaggregated data, which contribute to an understanding of the impact of tariff reduction on embodied CO_2 emissions.

Tariff reductions have a significant impact on embodied CO_2 emissions. Tariff reductions would increase the embodied CO_2 emissions of the import of manufacturing machinery, metal, food, paper, chemical and mining, gas, metal, and other sectors in G20 economies. While we analyze the impacts of tariff reform and environmental policy, we argue that the international tool is the consideration of small changes in the existing tariff reform, which can serve as an important change. By considering the above impacts, suitable changes in MFN tariffs can made to be ensure that every trading nation that participates in an international trade agreement experiences a strict welfare gain. More complex situations could be analyzed by incorporating the environmental degradation arising from consumption and/or production technologies. Considering this, additional countries could also be incorporated into the future research model. Our results show that embodied emissions in imports grow 3.5–232.2%, depending on the country, if we assume tariff free conditions. This scenario creates difficulty in achieving national emission reduction targets and in implementing national environmental policy. We suggest that globally consistent environmental policies such as global carbon pricing would be more effective in tariff free conditions.

For policy makers, is important to know how the underlying emission intensity forces affects the changes in CO_2 emissions embodied in the international trade. Since the carbon intensity of developing economies are still relatively high, there is considerable potential for further efficiency gains in terms of emission intensity. We argue that the improvement of emissions intensity in international trade will assist in seeking more effective climate policies.

However, these are historical estimates and thus do not reflect what might happen if significant taxes were applied to CO_2 emissions. This analysis has not addressed the issue of what would happen in the future if carbon emission reduction policies were adopted; rather, it has focused on what has happened in the past in an effort to determine if significant amounts of CO_2 are embodied in imports of manufactured and mining goods. Additional work is needed to examine the link between environmental regulations, international trade and environmental quality.

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