CARBON-MOTIVATED BORDER TAX ADJUSTMENT: POLICY DESIGNS COMPARISON

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Abstract:

The following analysis focuses on carbon-motivated border tax adjustments (CBTA), which are tariffs applied by countries implementing carbon control policies imposed on products imported from abroad. In particular we focus on CBTAs policy design, since CBTAs can be computed considering emissions embodied in imports, or referring to emissions avoided through imports. Using the WIOD database, we simulate through a multi-region and multi-sector analysis what tariffs system should be applied to products imported in Europe to compensate an European CO_2 emissions taxation, considering embedded emissions or avoided emissions. To know for which countries and sectors the method used is critical can help to understand and to add information to the political debate on it. Furthermore, an important novelty of our analysis is that we estimate avoided emissions not only using the traditional "domestic technology assumption", but also using a more appropriate approach that considers the physical quantities of imported goods.

1. Introduction

Within the framework of emission control instruments, there is currently an important debate regarding carbon-motivated border tax adjustment (CBTA) and its possible role to complement emission reduction policies. CBTAs are a trade instrument, consisting in tariffs applied by countries that are pricing carbon emissions, and they are aimed at preventing the main drawbacks of unilateral emission control mechanisms. If implemented, these tariffs would be imposed on products imported from all the countries that are not applying the carbon control policy in order to "level the carbon playing field",[1] compensating for the loss of competitiveness that a carbon tax may imply for domestic producers, and avoiding possible emission leakage involved in unilateral emission reduction policies (Lockwood and Whalley 2010, Horn Sapir 2013).[2] As Mattoo et al. (2009) and Kuik (2010) point out, the viability of this tool has already been considered at political level and included in policy proposals of countries like United States (US) and Europe. Indeed, in the 2009 US proposal for implementing an emission trade mechanism - the American Clean Energy and Security Act[3] - the border adjustment measure was included as a competitiveness measure to ensure the equal distribution of costs in the absence of an international agreement limiting emissions. Looking at the European Union (EU), the revised Emission Trading Scheme (ETS) directive (European Parliament and Council, 2009) asks for an assessment of the impact of carbon leakage on Member States and for the inclusion of importers in the Community scheme. Also international trade authorities such as the World Trade Organization (WTO) have already reckoned the relevance of CBTAs (see WTO 2009 and Hillman 2013).

One of the critical issues related to the implementation of CBTAs is its policy design, since tariffs can be compute through different methods. In particular, there are two main approaches to calculate a CBTA. One way is to compute the tariffs based on the emissions embodied in each imported products. Alternatively, the tariff could be computed on the emissions avoided through imports: in this case the tariff applied to any imported product would be based on the emissions embodied in the same good produced domestically. The debate revolves around three implications of the different policy designs. The first one is its legal acceptability as a trade instrument, considering the international legal framework established by the WTO. The second dimension is the CBTA environmental effectiveness, and the third one is the political feasibility in terms of practical implementation. On the one hand, tariffs calculated on avoided emissions are more justifiable as a trade policy considering that the WTO regulation detailed by GATT (1994) would accept indirect taxes related to products and not direct taxes related to producers or to their income (Mattoo et al. 2009, Hillman 2013). Moreover, CBTAs on avoided emissions would also be easier to be implemented, because they would imply no discrimination among exporting countries. On the other hand, they could be considered less effective as an environmental policy: indeed, tariffs on avoided emissions would not give any incentive for exporting countries to implement more environmentally-

[1] This expression is often used in CBTAs literature. See, for example, Houser et al. (2008).

[2] To better justify BTAs, Horn and Sapir (2013) refer to international externalities that arise when countries combat emissions unilaterally. Indeed, countries implementing unilateral climate policy face the full costs of their abatement efforts, receiving only part of the benefits that are spread across the world. As a result, they will typically choose sub-optimal climate policies exposing each other to more climate damage than would be internationally efficient, that is, exposing each other to international externalities.

[3] The American Clean Energy and Security Act (American House of Representative, 2009) was a US energy bill that, if approved by the Senate too, would have established an emission trading mechanism similar to the European Union Emission Trading Scheme.

friendly technologies. Then, if the main characteristic of this policy is its environmental purpose, CBTAs calculated on embodied emissions would have stronger justification.

Focusing on the different methods of designing a CBTA system, in the following analysis we simulate what tariffs system should be applied to the products imported in Europe in order to compensate an equivalent taxation on CO_2 emissions implemented within the EU. We focus in particular on Europe due to its position about carbon pricing. Indeed, on the one hand, the EU debate on pricing carbon emissions has a long history started in the early 1990s, and the EU is already implementing different policies for emission control such as the ETS or the European Energy Tax Directive (ETD), a tax on the use of energy products aimed at reducing emissions. On the other hand, these main policies implemented so far are still weak or poorly performing,[4] and there are ongoing political debates to strengthen them in order to reach the challenging environmental targets Europe has set itself.[5] Despite the political difficulties in advancing in carbon taxation in the EU, we believe it is important to revive the debate on implementing a harmonised EU carbon tax as a powerful climate change tool to reduce emissions. For this reason, since CBTAs have already been feared as possible for complementing a carbon tax, it seems important to analyse all the critical issues that they would imply, among them what method should be used to compute them. More in detail, the aim of our work is to analyze what differences would exist between CBTAs calculated on embodied emissions and CBAs calculated on avoided emissions, by using a multi-region and multi-sector analysis that permits to show to what extent the two policy designs would affect differently the countries or sectors that have trade relationships with Europe. To know for which countries and sectors the method used is critical can help to understand and to add information to the political debate on it.

There is an already vast literature on BTAs (see Ghosh et al. 2012 for a survey); anyway, due to the scope of our analysis, we focus in particular on the papers that compare different methods of computing the tariffs system (Mathiesen and Maestad 2002, Kuik and Hofkes 2009, Mattoo et al. 2009, Burniaux et al. 2010, Lin and Li 2011, Böhringer et al. 2012, and Elliott et al. 2012), or the papers that use a multi-region multi-sector analysis to determine CBTAs rates (Mattoo et al. 2009, Atkinson et al. 2011, Dissou and Eyland 2011, Böhringer et al. 2012, Elliott 2012, Ghosh et al. 2012, and Schenker et al. 2012). Among them, only three papers - Mattoo et al. (2009), Böhringer et al. (2012) and Elliott et al. (2012) - consider both issues together, using an input-output (IO) approach to compute and comparing different CBTAs designs.

Indeed, except from these three studies, all the analyses that compare different CBTAs designs do not use an IO approach to compute emissions embodied and emissions avoided. Instead, they consider the direct emissions of the different sectors through sectors' emission intensity, using in particular the emission intensities of target countries for computing embodied emissions, and the emission intensities in the countries implementing the policy for computing avoided emissions. Alternatively, Burniaux et al. (2010) consider for each sector the direct emissions (computed through emission intensities) and the indirect emissions that are the sum of direct emissions and emissions embodied in sectors' electricity use. Differently from this literature, we believe that considering all the emissions embodied in different goods through an IO approach is more appropriate. In fact, any carbon taxation could apply, domestically, to all sectors; in this case the final additional cost for any

[4] Indeed, the European ETD currently in force fixes very low tax rates for the most part of fuel uses and does not explicitly tax energy products according to their carbon emissions; looking at the ETS, during the last years the carbon price has been too low to give a strong price signal.

[5] In addition to the ETS Directive quoted above (European Parliament and Council, 2009), in 2001 the European Commission already proposed to modify the ETD in order to introduce an explicit carbon tax component (European Commission, 2011).

domestic good would depend on the direct emissions produced by its sector, but also on the pollution emitted when making all inputs needed to produce it. So, since the aim of CBTAs is to apply the same treatment to domestic and imported products, considering exporting countries that are not imposing the carbon taxation, many energy-intensive sectors such as electricity but also transportation are producing mostly non-tradable goods, but their emission content should be taken into account if they are used as an input to produce tradable goods that are then imported by the country applying the carbon tax.

Looking at the papers that propose a multi-region multi-sector analysis to determine CBTAs rates, they usually do not offer a comparison between different policy designs, because they focus on different issues related to CBTAs. In particular, Atkinson et al. (2011) compare the total emissions embodied in domestic production with the emissions embodied in consumption. They use IO information to find out the average tariffs but just considering the emissions embodied in imports through a bilateral trade IO approach.[6] They find that the main exporters of virtual carbon are China and Russia, while the main importers are EU, USA, and Japan; tariff rates would widely vary by country and by sector, the large developing countries showing tradable sectors such as chemicals or mineral products that would be particularly hit by CBTAs. Dissou and Eyland (2011) analyse different BTA recycling methods; they find that using CBTAs proceeds to support energy-intensive industries improves their competitiveness. Ghosh et al. (2012) focus on efficiency and distributional consequences of CBTAs calculated only on CO_2 emissions or CBTAs calculated on different greenhouse gases (GHG); the main finding is that CBTAs distributional implications are smaller under a broad-based GHG policy. Schenker et al. (2012) analyse CBTAs in terms of output variation, welfare effect, carbon leakage, and trade composition. They compare a full IO approach to an IO approach corrected for imports from regulating countries (Europe, Australia, Japan, Korea, and Taiwan), and they find that the two methods do not imply strongly different results.

Analyzing more in detail the three papers that consider both issues together, **Mattoo et al. (2009)** assess the different impact of CBTAs computed on embodied emissions and CBTAs computed on avoided emissions on several target countries, assuming unilateral emissions reductions of 17% by 2020 in high income countries (EU, USA, Japan, and other United Nations Framework Convention on Climate Change (UNFCCC) Annex-I countries). They use a computable general equilibrium model based on 2004 GTAP data. The main finding is that, on the one hand, CBTAs on embodied emissions would imply average tariffs for India and China of over 20% and would depress manufacturing exports between 16 and 21%. On the other hand, CBTAs on avoided emissions would address the competitiveness problems without so many damages for exporting countries. **Böhringer et al. (2012)** compute the efficiency impact of different CBTAs designs, analyzing three different regulating coalitions: Europe, UNFCCC Annex-I regions except for Russia, or a broad coalition that includes China. They simulate a unilateral cap at 80% of the abating regions' emissions. CBTAs vary among three dimensions: embodied carbon coverage (direct, direct and electricity-related, or total emissions), sector coverage (energy-intensive trade-exposed goods, or all goods), tariff rate differentiation (country- and sector-specific, or sector-specific tariffs). They find that systems more likely to comply with international law yield very little in terms of carbon leakage and efficiency. **Elliott et al. (2012)** analyze the extent of emission reduction of a wide range of carbon tax schemes in Kyoto protocol Annex-B countries, the expected carbon leakage, and the effect of CBTAs, simulating both CBTAs on embodied emissions as well as CBTAs on emissions related to production technologies in importing countries. Using 2004 GTAP data through a computational general equilibrium model, they show the

[6] Through this approach they consider only the carbon added by the exporting countries, and not the emissions embodied to produce the inputs that the exporting countries are importing from abroad.

importance of global taxes: carbon taxes only in Kyoto protocol Annex-B have low potential to reduce emissions. They also find that CBTAs on avoided emissions can be significantly inferior at reducing leakage than CBTAs on embodied emissions, mainly due to the lack of incentives for foreign producers to adapt less-polluting technologies.

Our work follows this research line, with some differences.

First, instead of focusing on the broad effects of CBTAs in terms of output, competitiveness or environmental goals as the previous literature does, we propose static analysis to show what tax level each policy design would imply. Comparing our proposal to Mattoo et al. (2009), Böhringer et al. (2012) and Eliott et al. (2012), these works do not provide an analysis of the different CBTAs designs at a sector level, because they address competitiveness, environmental, or efficiency concerns in global terms using computational general equilibrium models. On the contrary, we propose a sector-based country-based analysis. We think that this is an important contribution because the intensity but also the spread or concentration of the effect of BTAs designs in different countries and different sectors is an additional element to assess the feasibility of this policy. Moreover, while the previous studies use the GTAP database, we employ WIOD data that are better suited with the scope of our analysis.

Furthermore, our analysis explores an additional methodological issue about how to calculate the avoided emissions. Indeed, the estimation of avoided emissions is equivalent to compute the emissions of imported products applying the so called "domestic technology assumption" (DTA). As we have analysed in a previous article, the usual way of estimating emissions according the DTA has a problem that could significantly bias the outcomes (Arto et al., 2014), because the implicit assumption is that prices of imported goods are equal to prices of the same products produced at home. For this reason in this paper we estimate avoided emissions correcting for the differences in prices of imported and domestically produced goods using trade data in physical units as it is explained in Arto et al. (2014).

Finally, we summarize the results of our analysis through two different indices. The first one offers a synthetic measure of the CBTAs effect for each target country, considering the quantity exported by that country to the EU, in order to compare the CBTAs effect at a country level. The second index measures the effect of CBTAs within each European country considering its trade relations with non-European countries. Since one drawback of CBTAs is their negative effect for domestic producers using foreign inputs and for domestic consumers buying foreign products, this exercise permits to show what European countries would be most affected by CBTAs due to their international trade structure, so it permits to show some preliminary information also regarding the different obstacles this policy could meet within Europe.

2. Method

The input-output framework offers adequate instruments to the scope of our analysis. Indeed, the aim of a border tax system is to apply a fiscal treatment to imported products similar to the one applied to domestic products. When a carbon tax is implemented, the fiscal load charged on a domestic good is related not only to the pollution that a sector emits to make it, but also to the emissions contained in the inputs used to produce it, because also the sectors producing the inputs would be subject to the same tax. So, if a border tax wants to apply the same treatment to foreign products, it has to account for the input structure and the input emissions content of foreign products too, and the input-output analysis is a framework precisely constructed to do it.

As Arto et al. (2014) point out, the literature has extensively shown that two different methods are needed to compute emissions embodied in trade and emissions avoided through trade.

Emissions embodied in trade can be traced out using an environmentally-extended multi-regional input-output (ee-MRIO) model. In a world consisting in *c* countries, each of them composed of *n* sectors, the ee-MRIO model considers the equivalence between the total output of any sector *i* in country *r* (x_i^r) and how that output is consumed, domestically or abroad, by any economic sector *j* as an intermediate input $\left(x_{ij}^{rs}\right)$, or by final users as final output (f_i^{rs}): $x_i^r = \sum_{j=1}^{n}\sum_{s=1}^{c} x_{ij}^{rs} + \sum_{s=1}^{c} f_i^{rs}$. In matrix terms the same expression becomes $\mathbf{x} = \mathbf{X} + \mathbf{f}$, being $\mathbf{x}$ the $(\mathrm{n} \times \mathrm{c})$ vector of sectoral output, $\mathbf{X}$ the $\big((\mathrm{n} \times \mathrm{c}) \times (\mathrm{n} \times \mathrm{c})\big)$ matrix of all the inter-country inter-sector deliveries, and $\mathbf{f}$ the $(\mathrm{n} \times \mathrm{c})$ vector of final demand. The equivalence can be then transformed in $\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-\mathbf{1}}\mathbf{f}$. $\mathbf{A}$ is the matrix of input coefficients representing the world input structure, where each element a_{ij}^{rs} is obtained as $a_{ij}^{rs} = x_{ij}^{rs}/x_i^r$. Adding information on emissions per sectoral unit e_i^r obtained dividing the total sectoral emissions over the output produced by each sector, it is possible to compute the emissions embodied in each unit exported. Anyway, since CBTAs would be tariffs applied to foreign products, instead of computing the embodied emissions per sectoral unit, we compute the embodied emissions per each one of the m products any country r is producing. The $(\mathrm{m} \times \mathrm{c})$-dimensional vector $\mathbf{p_{ex}}$ of emission content p_l^r of the total export for each product l from any country r can be indeed calculated as $\mathbf{p}'_{\mathbf{ex}} = \mathbf{i}'\big(\hat{\mathbf{e}}(\mathbf{I} - \mathbf{A})^{-\mathbf{1}}\mathbf{W}\big)$: $\mathbf{i}$ is a one's vector of appropriate dimensions, $\hat{\mathbf{e}}$ is the matrix containing in the diagonal the $(\mathrm{n} \times \mathrm{c})$ emissions per sectoral unit e_i^r, while $\mathbf{W}$ is a $\big((\mathrm{n} \times \mathrm{c}) \times (\mathrm{m} \times \mathrm{c})\big)$ matrix containing the total export desegregated by sector and by product. The embodied emissions per product unit are equal to the vector of total emissions of exports by product $\mathbf{p}'_{\mathbf{ex}}$ divided by the vector of total exports by product $\mathbf{w}$ ($\mathbf{w} = \mathbf{i}' \times \mathbf{W}$).

The method needed to compute avoided emissions is an environmentally-extended single-region input-output (ee-IO) model, applying the so-called domestic technology assumption (DTA):[7] through this model we calculate the amount of emissions that would have been contained in a domestic product if all its inputs were produced domestically, with the technology available domestically. Applying the DTA is indeed useful in this context, as shown by the following simple example. Considering a cloth imported from India, the border tax on avoided emissions applied to it would be equal to the carbon tax charged on a European cloth. If the Indian cloth is then used to produce a blouse internally, the tax burden on the blouse produced in Europe using Indian cloth has to be equal to the tax charged on a European blouse made with European cloth in order to treat domestic and foreign products in the same way. For the same reason, in a regime of duties based on avoided emissions, the same fiscal load would be then applied also to a shirt directly imported from India. So, considering only one single region with n sectors, and applying the DTA, the n-dimensional vector $\mathbf{p_{im}}$ of emissions p_l avoided by importing any product l from abroad would be $\mathbf{p}'_{\mathbf{im}} = \mathbf{i}'\big(\hat{\mathbf{e}}_{\mathbf{d}}(\mathbf{I} - \mathbf{A_t})^{-\mathbf{1}}\mathbf{M}\big)$. $\mathbf{i}$ is a one's vector of appropriate dimensions, $\hat{\mathbf{e}}_{\mathbf{d}}$ is the matrix containing in the diagonal the n emissions per sectoral unit e_i. $\mathbf{A_t}$ represents the matrix of total input coefficients, sum of the domestic input coefficient matrix $\mathbf{A_d}$ and the matrix of imported input coefficient $\mathbf{A_m}$: $\mathbf{A_t} = \mathbf{A_d} + \mathbf{A_m}$.

[7] As explained in Arto et al. (2014), we maintain the acronym DTA often used in literature, although, previously, it was mostly used in a different context, to describe the foreign technology when MRIO data were not available.

$\mathbf{M}$ is a $(n \times m)$ matrix containing the total imports desegregated by sector and by product. The avoided emissions per product unit are equal to the vector of total emissions of imports by product $\mathbf{p}'_{\mathbf{im}}$ divided by the vector of total imports by product $\mathbf{m}$ ($\mathbf{m} = \mathbf{i}' \times \mathbf{M}$).

Since input-output data are expressed in monetary terms, when the DTA is used to compute avoided emissions an important issue related to the units considered arises, as it is extensively shown in Arto et al. (2014). When we calculate the emissions applying the DTA in monetary terms, we actually estimate the emissions produced by making the imported goods with the domestic technology, but we consider the value of imported goods instead of the physical quantities imported. Due to differences in prices among countries, it can be the case that the monetary value of imports would correspond to a different monetary value if the products imported would have been produced domestically. Or, in other terms, to calculate the emissions that would have been produced to make domestically all the products usually imported is important to adjust for the level of prices, or to deflate the value of imports in order to account for international price differences. So, following the suggestion of Arto et al. (2014), we compute emissions avoided by trade applying both, the "monetary DTA" and the "physical DTA" adjusting for price differences across countries. Appendix 1 explains in detail how deflators are computed.

Finally, two indices are computed, to show the effects of any CBTAs design on different countries, both European or target countries. In particular, for every European country we compute the cost of any CBTAs design as a percentage of the total value imported by that country from all the non-EU countries. In a similar way, for every non-EU country we compute the total load any CBTAs system would imply, as a percentage of the total value exported from that non-EU country to all the European countries.

3. Data description

The analysis requires three main data, which are MRIO tables, CO_2 emissions data and international trade data in physical and monetary units.

For MRIO and environmental data, we use the database made available by the WIOD project since April 2012 and updated in November 2013 (WIOD, 2013). The WIOD database consists of four main time series: world input-output tables and international supply and use tables (WIOT-ISUT); national input-output tables and national supply and use tables (NIOT-NSUT); socio-economic accounts (SEA); environmental accounts (EA). In particular, for MRIO tables, the study considers the information contained in the first series, WIOT-ISUT. These data, available for the years 1995-2011, refer to 27 European counties, 13 other major countries in the world and all the remaining regions aggregated in a single "rest of the world" region.[8] Among the different tables contained in the WIOT-ISUT series,[9] the world input output table at current prices for the year 2009 is used.[10] It is a

[8] See Appendix 2 for the complete list of countries.
[9] The full set of the WIOT-ISUT tables contains international supply and use tables at current and previous year prices, with use split into domestic and import by country (35 industries by 59 products), world input output tables at current and previous year prices (35 industries by 35 industries), and interregional input output tables for 6 regions (35 industries by 35 industries). The used classification is the "National Classification of Economic Activities" (NACE) Rev 1.1 (Eurostat, 2002), for industries, and "Classification of Product by Activities" (CPA) (Eurostat, 2008), for products.
[10] The year is chosen due to the time availability for data on CO_2 emissions. Data are expressed in million of US dollars. To convert them in euro, annual data about exchange rates made available by Eurostat (2014) are used.

symmetrical table "industry by industry", offering a desegregation of about 35 sectors for each country.[11] This industry-type table is estimated under the assumption of "fixed product sales structure", which states that each product has its own specific sales structure, irrespective of the industry where it is produced. Finally, to get information desegregated by product, we also use the 2009 international supply and use tables at current prices, where information is available for 59 CPA products.[12] In WIOT_ISUT data are expressed in monetary terms (millions of dollars).

For CO_2 emissions data, we use the EA made available by WIOD. WIOD satellite accounts record data about use of energy, emission of main greenhouse gases, emission of other main air pollutants, use of mineral and fossil resources, land use, and water use. This satellite accounts have the same sector breakdown (35 sectors) and geographical coverage (40 countries including 27 European countries, and the remaining regions aggregated in a single region "Rest of the World") as the WIOT-ISUT series, and they are available for the years 1995-2009. Air emission accounts include CO_2 emissions (in 1000 tonnes) desegregated by sector and energy commodity, and non-CO_2 emissions (in tonnes) by sector. CO_2 emissions include both energy-related air emissions – that result directly from the use of energy through fuel combustion – and non-energy related air emissions – that are not directly related to the combustion process, such as industrial process including mineral, chemical and other production sectors, agriculture including manure, agriculture soils and field burning and waste.[13]

Finally, we use data on international trade from the database COMEXT made available by Eurostat (Eurostat, 2015), using in particular data recorded following the 2002 classification CPA. This database contains statistics collected by member states on merchandise trade among EU countries and between member states and global partners for the period 1988-2014. Data are available for 283 trading partners and 881 products categories, and they are expressed in monetary terms (euro) as well as in physical term (kilograms). In particular, we use the information for the 14 non-European countries available in WIOD too (see Appendix 2 for a list), and information on 217 product.[14]

4. Results

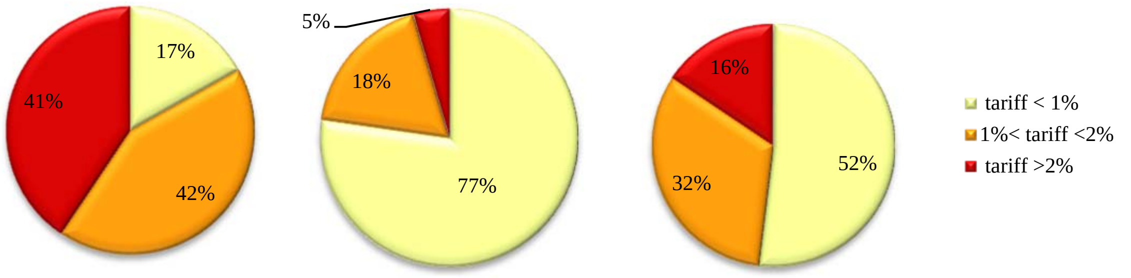
The simulation we propose shows the CBTAs rates that would apply on products imported from non-EU countries if Europe adopts a CBTA system to complement domestic carbon taxation equal to 20 euro per tone of CO_2 emitted. We fix the domestic carbon tax at this level because it is the CO_2 tax rate lately proposed by the European Commission - but not approved by the European Parliament – to implement a specific carbon component in the taxation on the use of energy products (European Commission, 2011), so it represents a tax level that could be realistically implemented by the EU. The CBTA rates are calculated by product, and they are computed based on the CPA disaggregation available in WIOD data. So, the rates shown in this analysis are indeed average tariffs, assuming a unique homogeneous good for each CPA classification.[15] Although data are disaggregated in 59 different categories, we focus our analysis on the 22 manufactured products, excluding agricultural products, raw material and services. We indeed assume that services would not be included in a CBTA system. Moreover, we also assume that CBTA tariffs would not be imposed on

[11] See Appendix 3 for the complete list of sectors.
[12] See Appendix 4 for the complete list of products available in WIOD.
[13] The matrix of CO_2 emissions is obtained by applying CO_2 emissions coefficients to emission relevant energy use data and then adding process-based emissions.
[14] See Appendix 5 for a complete list of the 217 products used from COMEXT (Eurostat, 2015).
[15] Actually each CPA category aggregates a wide variety of products. Reason why, starting from the results found in this analysis, a possible extension of this work could be a more desegregated analysis focused on the CPA products that would be charged most under a CBTA scheme. Anyway, this is not possible with WIOD data that instead permit a comparison among several countries and a multi-regional analysis.

products that do not have an equivalent good produced domestically, because the aim of a CBTA system would be to apply to foreign products the same fiscal regime implemented to domestic goods. Since for agricultural products and raw material the disaggregation available does not permit to distinguish between products that Europe is importing but also producing domestically from that products or raw material that the EU does not own and needs to import from abroad, we exclude them from the analysis. Table 1 shows CBTA rates computed on embodied emissions and CBTA rates computed on avoided emissions for each non-EU country. The rates found are directly related to emissions produced when making any product. Tax rates on embodied emissions vary by country because each country has a different technology for each product; regarding tax rates computed considering avoided emissions, while the emissions avoided by importing a product are the same independently of what country the product is imported from, the rates applied on the value of import vary among countries due to international differences in prices.

We compare first the two different tax designs considering all the products and all the countries in aggregate terms, finding that, as a global effect, CBTA tariffs would be higher in a system based on embodied emissions. To analyze the results in aggregate terms, in figure 1 we distinguish among products that would be more strongly affected through tariffs higher than 2%, products that would be mildly affected (with tariffs between 1% and 2%) and less affected products (with tariffs lower than 1%). In a system based on embodied emissions (Figure 1.a) for 41% of the totality of the 308 products considered (22 products for each of the 14 countries) the tariff applied would be more than 2%, while for the 42% of the products would be between 1% and 2%. In a CBTAs system calculated on avoided emissions (Figure 1.b) these percentages would be, respectively, 5% and 18%.

Figure 1. Percentage of products based on their tariff size, under the two different CBTAs designs



a. Embodied emissions **b. Avoided emissions (monetary)** **c. Avoided emissions (adjusted for price differences)**

Source: own elaboration.

This strong difference between CBTAs calculated on embodied emissions and CBTA calculated on avoided emissions is partially explained through international differences in prices. Adjusting for price differences (Figure 1.c) reveals that the most polluting products – or the products produced by the most polluting countries - are, on average, cheaper than European products, that implies that, after deflating data, the percentage of products strongly affected would be higher compared with the percentage found without adjusting for price differences (16% instead of 5%). Also mildly affected products, as the strongly affected ones, would be proportionally more when adjusting for price differences (32% instead of 18%). So, if on the one hand the impact of a system based on embodied emissions would be stronger, on the other hand this first result reveals that is necessary to take into account international price differences to avoid biased outcomes.

Table 1. CBTAs by product for any non-EU country, in percentage, corresponding to a 20 euro/ CO_2 tonne European carbon tax NEW DEFLATORS

			AUS		BRA		CAN		CHN		IDN		IND		JPN	
		CBTA AE*	CBTA EE**	CBTA AE_d***	CBTA EE	CBTA AE_d	CBTA EE	CBTA AE_d	CBTA EE	CBTA AE_d	CBTA EE	CBTA AE_d	CBTA EE	CBTA AE_d	CBTA EE	CBTA AE_d
15	**Food products and beverages**	0.8	1.1	1.0	0.7	1.6	1.0	0.5	2.0	0.6	0.9	1.8	3.7	0.8	0.6	0.3
16	**Tobacco products**	0.8	1.1	0.8	0.7	2.3	1.0	0.4	2.0	0.5	0.9	3.8	3.7	3.0	0.6	1.4
17	**Textiles**	0.7	1.2	0.7	0.6	1.2	1.2	1.5	2.8	2.1	3.8	2.5	3.8	1.6	0.8	0.5
18	**Wearing apparel**	0.7	1.1	0.7	0.6	1.0	1.0	0.4	2.8	1.5	3.8	1.0	3.8	1.4	0.8	0.2
19	**Leather and leather products**	0.5	1.1	1.8	0.5	0.9	0.9	0.9	2.1	2.6	1.8	1.0	2.3	1.1	0.7	0.3
20	**Wood and products of wood and cork**	0.7	1.2	0.8	0.5	0.8	1.1	0.9	2.9	0.9	1.6	0.6	5.1	0.7	0.9	0.2
21	**Pulp, paper and paper products**	0.7	1.1	0.7	0.7	0.8	1.1	0.7	3.9	0.5	2.8	0.6	5.3	0.6	0.9	0.1
22	**Printed matter and recorded media**	0.7	1.0	0.6	0.7	0.5	1.0	0.4	3.9	1.9	2.8	2.6	5.3	2.3	0.9	0.3
23	**Coke, refined petroleum products**	1.9	2.1	10.2	1.4	2.8	3.4	3.2	5.1	1.2	1.6	1.7	4.9	1.8	1.7	1.8
24	**Chemicals, chemical products**	1.1	2.0	1.0	1.1	3.5	2.2	1.3	5.5	2.5	2.2	8.1	5.1	2.4	1.6	0.4
25	**Rubber and plastic products**	0.7	1.5	0.5	0.8	0.7	1.2	0.8	4.2	1.4	2.1	1.1	4.5	1.3	1.1	0.4
26	**Other non-metallic mineral products**	2.9	4.1	1.4	3.2	3.6	2.9	4.4	10.1	7.6	12.3	6.1	12.9	4.7	3.7	0.7
27	**Basic metals**	1.2	2.2	0.5	1.6	1.1	2.0	0.3	6.4	1.7	6.7	0.5	8.3	1.7	1.9	0.6
28	**Fabricated metal products**	1.2	2.6	1.0	1.6	1.9	1.9	1.1	6.2	3.2	6.7	2.3	7.8	3.0	1.9	0.9
29	**Machinery and equipment n.e.c.**	0.6	1.7	0.5	0.8	1.1	1.1	0.4	4.0	1.7	1.5	1.3	4.5	1.4	0.9	0.5
30	**Office machinery and computers**	0.5	0.9	0.2	0.8	0.4	1.0	0.3	3.3	0.7	0.0	1.4	3.8	1.1	0.9	0.3
31	**Electrical machinery**	0.5	1.3	0.2	0.8	1.3	1.0	0.2	3.3	1.2	1.8	1.0	4.2	1.3	0.9	0.3
32	**Radio, television and comm. eq.**	0.5	1.4	0.7	0.8	1.3	1.0	0.4	3.3	1.4	1.8	0.7	3.8	2.2	0.9	0.7
33	**Medical and optical instruments**	0.5	1.3	0.3	0.8	1.2	1.0	0.5	3.3	4.2	1.8	0.8	4.0	1.9	0.9	0.5
34	**Motor vehicles, trailers**	0.6	1.2	0.4	0.7	0.7	1.0	0.6	3.3	1.6	1.3	0.8	4.1	0.9	0.9	0.5
35	**Other transport equipment**	0.6	1.2	1.0	0.7	0.6	1.0	0.9	3.3	1.1	1.3	2.2	4.5	1.5	0.9	0.6
36	**Furniture; other manufactured goods**	0.7	1.3	0.2	0.6	8.7	1.0	0.4	3.3	1.6	2.1	1.6	2.9	0.9	1.0	0.4
	Average tariff by country	**0.9**	**1.5**	**1.1**	**0.9**	**1.7**	**1.4**	**0.9**	**3.9**	**1.9**	**2.8**	**2.0**	**4.9**	**1.7**	**1.1**	**0.6**

Source: own elaboration. Non-EU countries: AUS: Australia; BRA: Brazil; CAN: Canada; CHN: China; IDN: Indonesia; IND: India; JPN: Japan.
* Carbon border tax calculated on the emissions avoided by Europe through trade.
** Carbon border tax calculated on emissions embodied in the products imported in Europe.
***Carbon border tax calculated on the emissions avoided by Europe through trade, adjusting for international prices differences.
- Product not exported to Europe.

Table 1. (Continuation) CBTAs by product for any non-EU country, in percentage, corresponding to a 20 euro/ CO_2 tonne European carbon tax

			KOR		MEX		RUS		TUR		TWN		USA		ROW	
		CBTA AE*	**CBTA EE****	**CBTA AE_d*****	**CBTA EE**	**CBTA AE_d**	**CBTA EE**	**CBTA AE_d**	**CBTA EE**	**CBTA AE_d**	**CBTA EE**	**CBTA AE_d**	**CBTA EE**	**CBTA AE_d**	**CBTA EE**	**CBTA AE_d**
15	**Food products and beverages**	0.8	1.6	0.5	1.1	0.8	2.2	1.7	1.2	0.7	1.5	1.2	1.4	0.9	1.3	1.0
16	**Tobacco products**	0.8	1.6	1.0	1.1	0.5	2.2	1.0	1.2	0.7	1.5	0.8	1.4	0.9	1.3	2.2
17	**Textiles**	0.7	2.1	1.3	1.6	1.2	2.6	2.0	1.1	1.4	2.7	1.5	1.5	0.8	1.7	2.0
18	**Wearing apparel**	0.7	2.1	1.4	1.6	0.6	2.6	0.8	1.1	0.9	2.7	1.7	1.4	0.7	1.6	1.3
19	**Leather and leather products**	0.5	1.6	0.7	1.1	0.8	2.7	1.4	0.9	1.2	1.6	1.4	1.4	1.1	1.5	1.1
20	**Wood and products of wood and cork**	0.7	1.9	0.3	1.4	0.3	3.3	1.3	2.2	0.6	1.5	0.4	1.8	0.6	1.5	0.9
21	**Pulp, paper and paper products**	0.7	2.1	0.5	1.4	0.7	3.1	0.7	1.3	0.8	2.6	0.3	1.3	0.5	1.5	0.7
22	**Printed matter and recorded media**	0.7	2.1	1.5	1.4	0.3	3.1	0.7	1.3	1.5	2.6	0.8	1.1	0.5	1.5	1.2
23	**Coke, refined petroleum products**	1.9	2.6	1.8	3.2	16.8	5.4	2.0	2.5	1.6	3.4	1.9	2.3	2.9	3.5	2.0
24	**Chemicals, chemical products**	1.1	2.7	2.2	1.7	2.3	9.5	3.3	1.4	2.6	3.8	1.6	1.9	0.8	3.4	1.5
25	**Rubber and plastic products**	0.7	2.1	0.8	1.6	0.6	4.5	0.7	1.9	1.0	2.3	0.9	1.4	0.4	8.0	1.0
26	**Other non-metallic mineral products**	2.9	7.4	1.6	5.2	3.3	12.8	7.8	7.4	4.9	12.3	4.2	4.9	1.3	7.1	6.4
27	**Basic metals**	1.2	4.1	0.9	2.3	1.2	10.3	1.3	2.7	2.0	4.2	1.3	1.9	0.9	2.8	0.7
28	**Fabricated metal products**	1.2	4.1	2.2	2.2	1.4	10.3	3.0	2.5	2.6	4.2	2.9	1.9	0.7	2.8	1.5
29	**Machinery and equipment n.e.c.**	0.6	1.9	1.1	1.3	0.7	4.5	1.2	1.5	1.4	1.8	1.1	1.0	0.5	1.9	0.6
30	**Office machinery and computers**	0.5	1.7	0.3	1.6	0.3	4.3	0.3	0.9	0.6	1.7	0.4	0.7	0.4	1.9	0.4
31	**Electrical machinery**	0.5	1.7	0.6	1.6	0.4	4.3	1.1	2.3	1.2	1.7	0.5	0.7	0.2	2.0	0.6
32	**Radio, television and comm. eq.**	0.5	1.7	0.5	1.6	0.4	4.3	0.8	1.2	1.0	1.7	0.7	0.7	0.6	1.9	1.1
33	**Medical and optical instruments**	0.5	1.7	1.3	1.6	0.8	4.3	0.2	1.2	3.1	1.7	1.6	0.7	0.4	2.2	0.5
34	**Motor vehicles, trailers**	0.6	1.8	0.9	1.1	0.6	3.4	1.0	1.2	0.7	1.7	0.9	1.1	0.5	1.5	0.8
35	**Other transport equipment**	0.6	1.8	0.2	1.1	1.6	3.4	3.1	1.3	0.8	1.7	0.9	1.1	0.8	1.5	0.4
36	**Furniture; other manufactured goods**	0.7	1.9	1.0	1.7	1.2	4.1	0.7	1.5	1.2	1.9	1.2	0.9	0.7	4.2	1.1
	Average tariff by country	**0.9**	**2.4**	**1.0**	**1.7**	**1.7**	**4.9**	**1.6**	**1.8**	**1.5**	**2.8**	**1.3**	**1.5**	**0.8**	**2.6**	**1.3**

Source: own elaboration. Non-EU countries: KOR: Korea; MEX: Mexico; RUS: Russia; TUR: Turkey; TWN: Taiwan; USA: United States; ROW: Rest of the World.

* Carbon border tax calculated on the emissions avoided by Europe through trade.

** Carbon border tax calculated on emissions embodied in the products imported in Europe.

***Carbon border tax calculated on the emissions avoided by Europe through trade, adjusting for international prices differences.

- Product not exported to Europe.

4.1. Analysis at the product level

Analyzing the results at a product level, the difference between the two approaches found in aggregate terms still exists, although some anomalies can also be found. In this section we propose a product-based analysis, looking first at the results obtained assuming CBTAs on embodied emissions, and then comparing them with CBTAs computed on avoided emissions.

If we look at the tariffs obtained simulating a system based on embodied emissions, the CPA category mostly affected would be “other non-metallic mineral products” (26);[16] for these products, the average rate would be higher than 2% in all the 14 non-EU countries considered, being particularly high (more than 10%) for products imported by China, Indonesia, India, Russia, and Taiwan (respectively, 10.1%, 12.3%, 12.9%, 12.8%, 12.3%). Among all the manufactured products analyzed, these products are the ones whose emissions depend most on domestic technologies: for all the countries considered except for Canada the emissions produced by each country are at least the 90% of total emissions embodied in these products. But, while for Indonesia and India these emissions are largely due to the technology of the sector producing “other non-metallic mineral products”, in the case of China and Russia an important share of emissions (32.1% and 32.8%) are embodied in the electricity need to produce them. As regards Taiwan, one fifth of embodied emissions are related instead to the extraction of raw material.

Other products that would be particularly affected are “basic metals” (27), and “fabricated metal products” (28). For these products, rates would be high in particular for Russia (10.2%), India (8.2%, 7.4%) followed by Indonesia (6.7%), and China (6.3% and 6.2%). China, India, Russia and Taiwan would also have the highest rates on other energy-intensive products “coke, refined petroleum products” (23), “chemicals, chemical products” (24). For all these products, the analysis reveals a pattern of embodied emissions very similar to the one described for “other non-metallic mineral products”: on average, for the countries analyzed, roughly the 80% of embodied emission are produced domestically. For “basic metals” (27), and “fabricated metal products” (28) produced in Russia and Indonesia emissions are mainly due to the intensive use of energy of the producing sectors; for Chinese and Indian products belonging to these classifications, and for “coke, refined petroleum products” (23) or “chemical products” (24) from the countries listed before, roughly half of the emissions embodied are due to the electricity needed to produce them. Some of these products would also have rates higher than 2% when imported from Australia, Canada, Korea, Mexico, Turkey and USA, but in this case the contribution to emissions of the electricity sector would be much lower.

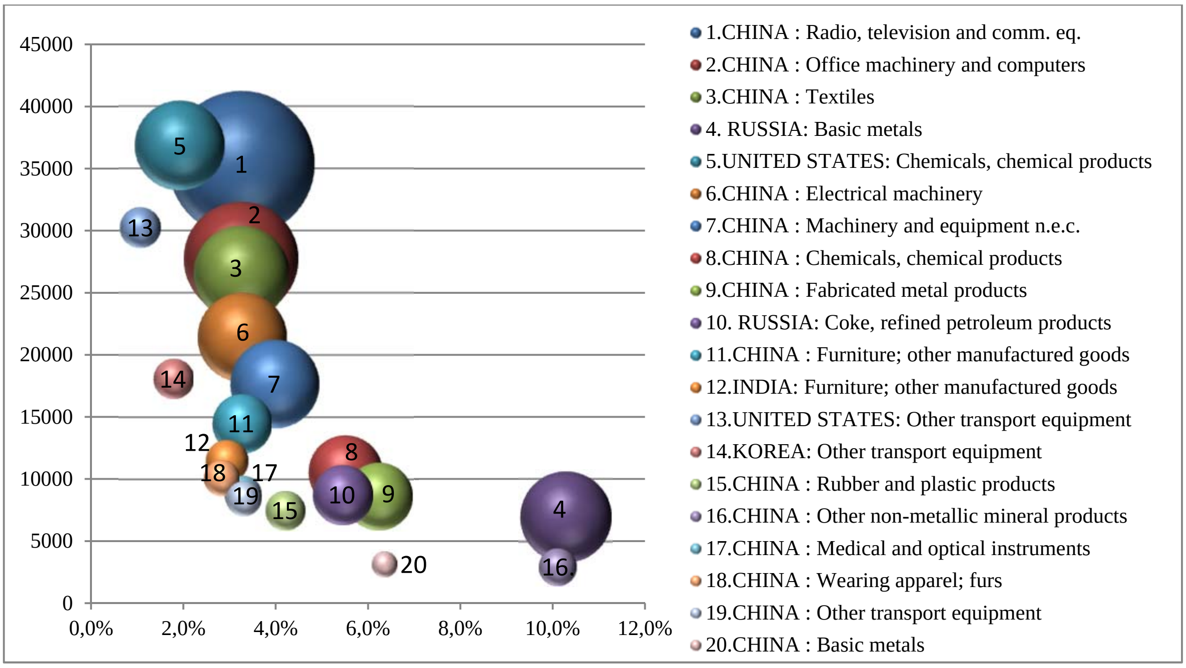
There are finally other products that would be taxed most, but just when produced and imported by few countries, in particular China, India, and Russia. For these three countries, many products would be taxed with rates higher than 3%: “wood and products of wood and cork” (20), “pulp, paper and paper products” (21), “printed matter and recorded media” (22), “machinery and equipment” (29), “office machinery and computers” (30), “electrical machinery” (31), “radio, television, and communication equipment” (32), “medical and optical instruments” (33), “motor vehicles, trailers” (34), “other transport equipment” (35). Once again, what these three countries have in common is that they rely most on domestic production (for all these products more than 90% of embodied emissions are produced domestically) and they also have in common a relevant role of the electricity sector in creating the emissions embodied in these products (for these products, on average, 47% of embodied emissions are due to the electricity sector). So, to conclude, looking at tax rates at a product level, the main products affected would be the energy-intensive products, in particular when

[16] The number in parenthesis after a product’s name refers to the product’s number in table 1.

imported from China, Indonesia, India, Russia, Korea, and Taiwan; the many emissions embodied in energy-intensive products coming from these countries are clearly related to the technology needed to produce them, but also, especially for China, India, and Russia, to the highly polluting electricity sector.

Always at a product level, a slightly different picture is shown if, instead of considering only the taxation level obtained, we also consider the trade volume, by country and by product, between the regions analyzed and Europe. Figure 2 shows the 20 products, over the 308 analyzed, mostly affected by a CBTA system based on embodied emissions: these products would indeed bear more than the 60% of the total cost of the policy, represented by the size of each bubble, computed as the tax rates (shown in the horizontal axis) multiplied by the total value imported in Europe (shown in the vertical axis).[17] The main result that Figure 2 shows is that 14 out of 20 products would be imported from China that alone would sustain roughly 30% of the policy's cost. The ranking of these products seems to be more related with the volume of trade than the severity of the rates imposed.

Figure 2. 20 products most affected by a CBTA system based on tax rates and trade volume.



The fifth and the thirteenth products that would bear most the cost of the CBTA would be "chemical products" (24) and "other transport equipment" (35) imported from USA: although tax rates would not be very high (respectively 1.9% and 1.1%), the volume of trade with Europe is very large. Conversely, very high tax rates more than the trade volume explain the cost the reform would implies on Russian products classified "coke, refined petroleum products" (23), and "basic metals" (27).

Comparing the results obtained simulating CBTAs on embodied emissions with the results obtained by assuming CBTAs on avoided emissions, three main characteristics are worth being noticed.

[17] The region that would actually bear the most part of a CBTA system is the region "Rest of the World" (ROW) that would pay roughly the 40% of the policy's cost. Anyway, we do not analyse the region ROW in detail because it aggregates several and different countries, and it would not be possible to provide a more detailed explanation to the results found.

First, the emissions Europe is avoiding, or the emissions that Europe would have produced if all products were made domestically, are on average very few. If we consider, for the 22 products analyzed, the emissions Europe would have generated producing all the inputs domestically, and we compare them with the emissions the other 14 regions are producing, out of 308 comparisons only in 12 cases the emissions embodied in foreign products would be less than the emissions avoided by Europe. This does not mean that Europe is actually polluting less than all the other countries or has the cleanest technology,[18] but it means that, if the EU produced domestically all the inputs imported, the environmental impact would be very low.

Anyway, a second important result is that, in the context of the analysis on CBTA designs we propose, a comparison between rates obtained on embodied emissions and rates obtained considering avoided emissions has to be adjusted taking into account international differences in prices, since applying the same treatment to domestic products and to foreign products cannot depend on prices differences. The results shown in table 1 reveal that adjusting for differences in prices changes substantially the results: while the average rate on avoided emissions without deflating data would have been 0.9%, when data are deflated the average rate would be 1.4%. In any case, also taking into account international differences in prices, in general a system based on avoided emissions implies tariffs lower than in a system based on embodied emissions: only for 15% of the products analyzed (42 out of 308) a system based on avoided emissions would imply rates higher than a system based on embodied emissions.

Finally, taking into account that 15% of goods that would be more affected by a system based on avoided emissions, the products that would be taxed more under a system based on avoided emissions are concentrated in few CPA categories, in particular “tobacco products” (16) imported from Brazil, Indonesia and Japan, “textiles” (17) from Brazil, Indonesia and Turkey, “leather products” (19) from Austria, Canada, and Turkey, and “chemical products” (24) imported from Brazil, Indonesia, and Turkey. This implies that these specific products imported from the listed countries are produced through very clean technologies able to produce a small amount of emissions compared with Europe. From these results it is also evident that CBTAs based on avoided emissions would be higher than CBTAs on embodied emissions manly in three countries: Brazil, Indonesia, and Turkey. In the following session we focus more in deep on specific countries to show the overall effect of the two tax designs for any of them.

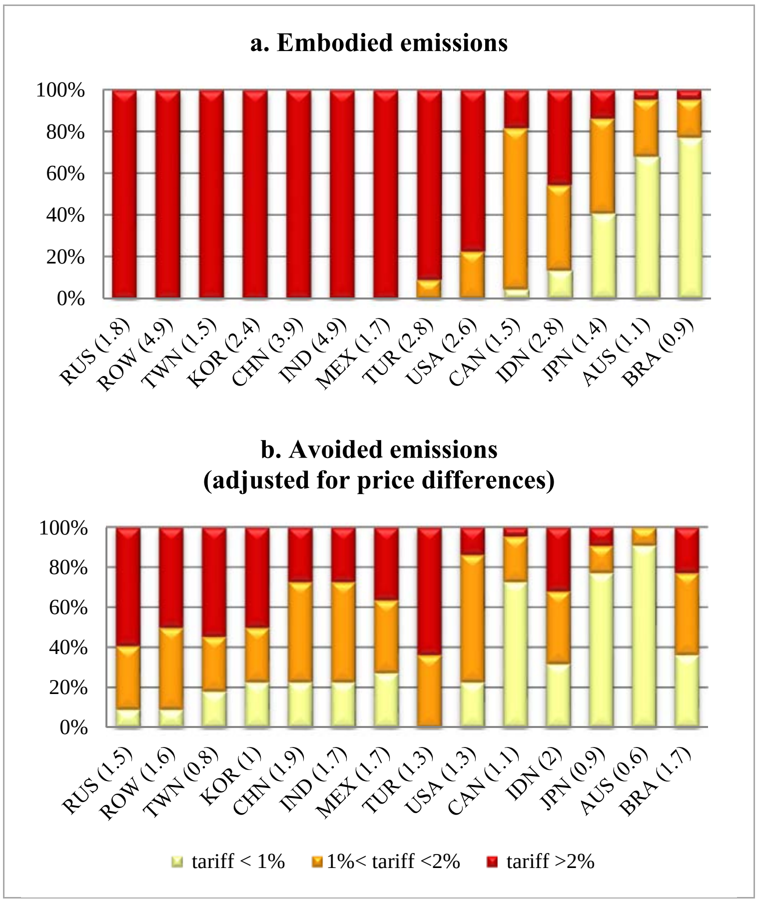
4.2. Analysis at the country level

Looking at the tax rates under the two regimes, the variance between the two approaches can be found at a country level too and also in this case with important differences across them, as shown in Figure 3, where countries are ordered based on the spreading of the CBTA on embodied emissions (Figure 3.a). For each country the label also shows, in parenthesis, the average tariff applied. For two countries, China and India, the differences between the two approaches would be very strong: considering embodied emissions, 100% of their products would be charged with tariffs higher than 2%, and the average tariff would be, respectively, 3.9% and 4.9%. Considering instead avoided

[18] To know what country possesses the cleanest domestic technology we should compare European and foreign domestic emissions intensities, or European and foreign avoided emissions. In the comparison proposed here we instead consider European avoided emissions and foreign embodied emissions.

emissions only 27% of products would be mostly affected, and the average tariffs would be 1.9% and 1.7%.

Figure 3. Percentage of products based on their tariff size, by country, under the two different CBTAs designs



Source: own elaboration.

Although in a less decisive way, also for almost all the other countries analyzed a CBTA system based on embodied emissions would have a strong impact than CBTAs based on avoided emissions in both dimensions, the level of the rates and their spread across products, although the difference is less strong for Turkey, USA, Canada, Indonesia, Japan, and Australia. The country that performs differently from the rest of the regions analyzed is Brazil: indeed for this region a tariff system based on avoided emissions would be clearly worse than a system based on embodied emissions. In particular, 16 products (73%) would be taxed more under a system designed on avoided emissions. One of the reasons can be found in the contribution of the electricity sector to emissions: Brazil is indeed the country with the less polluting energy sector, producing on average, for each unit produced, only one fifth of the emissions provoked by the second less polluting country (Canada), and 80 times less than the most polluting one (India).

Also analyzing the results at a county level it is interesting to show not only the effect in terms of rates, but also in terms of the cost that the two different designs would imply. Table 2 shows the cost of the two different CBTA designs for each country, considering in the first four columns the cost the policy would represent in relative terms, as a percentage of the value of manufactured products imported from any country by Europe, and also as a percentage of the total value of all products and services imported from each country by Europe. In the following columns Table 2 shows the share of the cost each country would bear.

For all countries except for Brazil, the cost on a CBTA system based on embodied emissions would be higher, although for some countries such as Australia, Indonesia, Japan, and USA, the difference between the two designs would be very small, while for countries like China, India, Korea, Russia, and Taiwan, the difference would be more relevant. Considering the cost as a percentage of manufactures imported in Europe, Russia would be the most affected country under a system based on embodied emissions, although the relative cost is very different if we consider all the Russian products imported in Europe: being raw material the most important trade flow with Europe, the cost of CBTA based on embodied (avoided) emissions would be the 7.2% (1.8%) of manufactures but only the 1.8% (0.4%) of the total value imported from Russia. Considering total imports, China would be the country most affected under the two different approaches, and it would also be the country that pays the higher cost share, and this confirms the results shown in Figure 1 and previously analyzed. A very interesting result regards USA: although a CBTA on embodied (avoided) emissions would represent only the 1.3% (0.8%) of the manufactures' value imported from USA, and the 0.6% (0.4%) of the total value imported, USA would be the second country in terms of share of the policy cost, bearing the 7.5% (8.8%) of the total cost of the policy. This is due to the fact that the volume of trade between USA and Europe very large.

Table 2. CBTA cost for each non-EU country

Non-EU Country	Percentage of the value of manufactured and total import to EU countries								Country's share of the policy cost			
	Embodied emissions				Avoided emission (deflated)				Embodied emissions		Avoided emission (deflated)	
	Manufactured import		Total import		Manufactured import		Total import					
Australia	1.6	[9]	0.5	[13]	1.1	[8]	0.3	[12]	0.3	[14]	0.5	[14]
Brazil	0.8	[14]	0.3	[14]	1.7	[4]	0.7	[7]	0.6	[12]	2.4	[9]
Canada	1.5	[11]	0.5	[12]	0.9	[10]	0.3	[13]	0.7	[11]	0.9	[12]
China	3.6	[3]	2.9	[1]	1.7	[3]	1.4	[1]	29.6	[2]	29.1	[2]
Indonesia	2.1	[6]	1	[8]	1.9	[1]	0.9	[3]	0.8	[10]	1.5	[11]
India	4	[2]	2.2	[2]	1.4	[5]	0.8	[5]	5.3	[5]	3.9	[5]
Japan	1.1	[13]	0.9	[9]	0.6	[14]	0.5	[9]	2.4	[8]	2.6	[7]
Korea	2	[7]	1.6	[4]	0.7	[13]	0.6	[8]	3.5	[6]	2.4	[8]
Mexico	1.5	[10]	0.5	[11]	0.8	[11]	0.3	[14]	0.4	[13]	0.5	[13]
Russia	7.2	[1]	1.4	[5]	1.8	[2]	0.4	[11]	5.7	[4]	2.9	[6]
Turkey	1.7	[8]	1.3	[7]	1.4	[6]	1	[2]	3	[7]	4.9	[4]
Taiwan	2.3	[5]	1.8	[3]	1.1	[9]	0.9	[4]	1.6	[9]	1.6	[10]
Usa	1.3	[12]	0.6	[10]	0.8	[12]	0.4	[10]	7.5	[3]	8.8	[3]
Row	2.6	[4]	1.4	[6]	1.3	[7]	0.7	[6]	38.5	[1]	38	[1]

Source: own elaboration.

*Countries ranking: [1] is the most affected country, [14] is the less affected.

5. Conclusions

In this paper we have analyzed one of the critical issues concerning the implementation of a CBTA system. This policy, which consists in imposing duties on foreign products when imported, is designed to complete an instrument of emission control, as it can be a carbon tax, which falls only on domestic products: apply tariffs to imported products would serve not to discriminate domestic products that fall within a tax regime applied only locally. Analyzing how a CBTAs system could be designed, one of the critical points is the calculation of tariffs, which could be based either on emissions actually contained in the imported goods, or alternatively may be fixed considering the imposition falling on domestic products, in order to treat domestic and imported goods exactly in the same way. In the first case, to calculate the duties is necessary to go back to the emissions that enter the atmosphere when the different countries produce goods that are then imported. In the second case, since both the domestic carbon tax and the CBTAs on imported inputs would fall on domestic products, to calculate the overall tax burden applied to domestic goods (which should then be applied also to imported products) is necessary to calculate the emissions that the country would produce making domestically all goods and all the necessary inputs. In this paper we have proposed a comparison between these two possible tariffs designs, simulating the CBTAs rates that would apply on products imported from non-EU countries if Europe adopts a CBTA system to complement domestic carbon taxation equal to 20 euro per tone of CO_2 emitted.

Looking at the main results found, this analysis proposed shows, first, the importance of adjusting data considering price differences among countries in order to compute rates applied under a system of avoided emissions: without deflating data the results would under-estimate the CBTA rates applied to imported foreign products. A second result is that the two different mechanisms would imply a very different outcome: in aggregate terms, a system designed considering embodied emissions would cost 2.5% of the total value of manufactures imported in Europe from the countries studied, while under a system based on avoided emissions the policy would cost the 1.3% of the manufactures' value imported. The difference between the two designs analyzed then varies depending on the countries considered: for some countries the rates computed under the two systems would be similar as for Australia, Indonesia, Japan, and USA, while for other countries the difference would be really high. On the one hand a possible conclusion could be that a system based on a avoided emissions is likely to be more acceptable due to its lower cost and due to the fact that products would not be differently treated depending on their origin. On the other hand the analysis also makes it clear that a system based on avoided emissions would not be targeted at the real pollution content of the different goods, either foreign products or domestic ones: this implies that the policy would ultimately depart from its main objective, namely the regulation and reduction of emissions through market mechanisms. In terms of analysis by product, even if almost all the goods analyzed would be subject to higher rates in a system based on embodied emissions, the difference between the two designs would be greater for energy-intensive products (such as coke, refined petroleum products, chemicals, chemical products, other non-metallic mineral products, basic metals, and fabricated metal products), and even more for those energy-intensive products imported from countries with a highly contaminating electricity sector, such as China, India, and Russia. Interestingly, these are the countries that would be the most affected. The analysis also shows that USA would bear an important share of the CBTA cost under both designs, although the policy's cost would represent less than the 2% of the manufactures the country imports in Europe. Finally, not for all the countries considered a system based on embodied emissions would be less expensive: the analysis in fact shows that, in the case of Brazil, the average content of emissions is limited especially thanks to an extremely clean electricity production system: under a system based on avoided emissions Brazilian products would be taxed more than under a system that takes into account the emissions actually contained in them. Also this result reinforces the idea that a system based on avoided emissions can go in the opposite direction of a policy, such as a carbon tax, which seeks to create incentives to reduce emissions.

6. Appendices

Appendix 1. Computing deflators

To compute the deflators used in the analysis, data on domestic and foreign products expressed in monetary and in physical terms are needed: each deflator is indeed the ratio between the domestic price of any European product and the foreign price of the same good produced abroad, and each price is obtained dividing the total value in monetary terms over the physical quantity produced, domestically or by the foreign country. Since data in physical terms are available only for international trade flows, due to data availability we assume that the price of products exported from Europe is the same as the domestic price of European products. As for the imports, international trade data permit to find directly import prices. While data in physical quantities are available only in COMEXT database, data in monetary terms are available in both COMEXT and WIOD databases. Both databases use the same CPA product classification, but choosing on or the other source implies making a different assumption. On the one hand, by using data in monetary terms from COMEXT, the prices obtained are the ones implicit in COMEXT database because also data on quantities are from the same database. Since the deflators are then applied to WIOD import data, in this case the assumption is that prices in the two databases are the same. On the other hand, using data in monetary terms from WIOD implies finding directly the prices of the WIOD database, but assuming that the quantities recorded in the two databases are the same.

We choose the first option for three main reasons. First, both databases record imports in “Cost, Insurance and Freight” (CIF) prices and exports in “Free On Board” (FOB) prices: so, although in the first method we obtain the prices implicit in COMEXT database and then we apply them in WIOD assuming that prices are the same, this assumption seems to be realistic. A second reason to chose COMEXT data is that in the WIOD database data on imports and exports disaggregated by product, country, and sector are obtained by adjusting to maintain domestic accounts faithful to the national data sources and this could implies some approximations in WIOD trade data that are indeed less adequate do be compared with data on quantities from COMEXT. Third, using data in monetary terms from COMEXT has a further advantage since data are more disaggregated than in WIOD. Indeed using aggregated data could cause a bias in the deflators computed, just because the relative weight of different sub-products belonging to the same aggregate category is different. Let consider a simplified numerical example, where Europe exports to and imports from a non-European country two different manufactured food products, yogurt and wine, and let assume that, while European yogurt exported is twice as expensive as the imported yogurt (P_y^E =4, P_y^I=2), the price of a bottle of wine is the same ($P_w^E = P_w^I$ =10). Finally, let imagine that Europe exports 10 units of yogurt and 10 bottles of wine (Q_y^E=10, Q_w^E=10) and imports 50 units of yogurt and 10 bottles of wine (Q_y^I=50, Q_w^I=10). The values of exported and imported goods are indeed: V_y^E=40, V_w^E=100, V_y^I=100, V_w^I=100. If data on values and quantities available are disaggregated, dividing the values over the quantities of yogurt and wine exported and imported we obtain the original prices, and the deflators obtained are equal to 2 for yogurt, 1 for wine. If data on values and quantities for the two products are instead aggregated (V^E=140, V^I=200, Q^E=20, Q^I=60), we would obtain a price for the unique good exported (P^E=7) and a price for the unique product imported (P^I=3.3) biased by the relative weight of each product, resulting in a deflator equal to 2.1, which would be greater than the highest deflator obtained with disaggregated data. We indeed choose COMEXT data because they are more disaggregated. So, to compute a deflator for each WIOD product, we compute prices of imports and exports with the highest disaggregation possible, and then we aggregate in a single price for each WIOD category weighting the export prices for the quantities imported. In the previous numerical example, we would obtain an “adjusted” aggregated price of export equal to 5 ($P^E_{adjusted}$= ((P_y^E* Q_y^I)+ (P_w^E* Q_w^I))/(Q_y^I+ Q_w^I) =5), and a deflator equal to 1.5. An alternative way would be, inversely, to adjust the import price for the quantities exported. We choose the first alternative because the deflators obtained are then applied to adjust products imported by Europe.

Appendix 2. Countries considered

European Countries	Denmark	Ireland	Poland	UK	Indonesia	Taiwan
	Estonia	Italy	Portugal	**Non-European Countries**	India	United States
Austria	Finland	Latvia	Romania		Japan	Rest of the World
Belgium	France	Lithuania	Slovak Republic	Australia	Korea	
Bulgaria	Germany	Luxemburg	Slovenia	Brazil	Mexico	
Cyprus	Greece	Malta	Spain	Canada	Russia	
Czech Republic	Hungary	Netherland	Sweden	China	Turkey	

Source: own elaboration.

Appendix 3. Sectors considered

Sector number	WIOD code	Sector
1	AtB	Agriculture, hunting, forestry and fishing
2	C	Mining and quarrying
3	15t16	Food, beverages and tobacco
4	17t18	Textiles and textile products
5	19	Leather, leather and footwear
6	20	Wood and products of wood and cork
7	21t22	Pulp, paper, paper , printing and publishing
8	23	Coke, refined petroleum and nuclear fuel
9	24	Chemicals and chemical products
10	25	Rubber and plastics
11	26	Other non-metallic mineral
12	27t28	Basic metals and fabricated metal
13	29	Machinery, nec
14	30t33	Electrical and optical equipment
15	34t35	Transport equipment
16	36t37	Manufacturing, nec; recycling
17	E	Electricity, gas and water supply
18	F	Construction
19	50	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel
20	51	Wholesale trade and commission trade, except of motor vehicles and motorcycles
21	52	Retail trade, except of motor vehicles and motorcycles; repair of household goods
22	H	Hotels and restaurants
23	60	Inland transport
24	61	Water transport
25	62	Air transport
26	63	Other supporting and auxiliary transport activities; activities of travel agencies
27	64	Post and telecommunications
28	J	Financial intermediation
29	70	Real estate activities
30	71t74	Renting of m&eq and other business activities
31	L	Public admin and defence; compulsory social security
32	M	Education
33	N	Health and social work
34	O	Other community, social and personal services
35	P	Private households with employed persons

Source: own elaboration from WIOD database.

Appendix 4. WIOD Products considered

Product number	WIOD code	Product
1	1	Products of agriculture, hunting and related services
2	2	Products of forestry, logging and related services
3	5	Fish and other fishing products; services incidental of fishing
4	10	Coal and lignite
5	11	Crude petroleum and natural gas
6	12	Uranium and thorium ores
7	13	Metal ores
8	14	Other mining and quarrying products
9	15	Food products and beverages
10	16	Tobacco products
11	17	Textiles
12	18	Wearing apparel
13	19	Leather and leather products
14	20	Wood and products of wood and cork (except furniture), articles of straw and plaiting materials
15	21	Pulp, paper and paper products
16	22	Printed matter and recorded media
17	23	Coke, refined petroleum products and nuclear fuel
18	24	Chemicals, chemical products and man-made fibres
19	25	Rubber and plastic products
20	26	Other non-metallic mineral products
21	27	Basic metals
22	28	Fabricated metal products, except machinery and equipment
23	29	Machinery and equipment n.e.c.
24	30	Office machinery and computers
25	31	Electrical machinery and apparatus n.e.c.
26	32	Radio, television and communication equipment and apparatus
27	33	Medical, precision and optical instruments, watches and clocks
28	34	Motor vehicles, trailers and semi-trailers
29	35	Other transport equipment
30	36	Furniture
31	37	Recovered secondary raw materials
32	40	Electrical energy, gas, steam and hot water
33	41	Collected and purified water, distribution services of water
34	45	Construction work
35	50	Trade, maintenance and repair services of motor vehicles and motorcycles
36	51	Wholesale trade and commission trade services, except of motor vehicles and motorcycles
37	52	Retail trade services, except of motor vehicles and motorcycles
38	55	Hotel and restaurant services
39	60	Land transport and transport via pipeline services
40	61	Water transport services
41	62	Air transport services
42	63	Supporting and auxiliary transport services
43	64	Post and telecommunication services
44	65	Financial intermediation services, except insurance and pension funding services
45	66	Insurance and pension funding services, except compulsory social security services
46	67	Services auxiliary to financial intermediation
47	70	Real estate services
48	71	Renting services of machinery and equipment without operator and of personal and household goods
49	72	Computer and related services
50	73	Research and development services

Source: own elaboration from WIOD database.

Appendix 4. (Continuation) WIOD Products considered

Product number	WIOD code	Product
51	74	Other business services
52	75	Public administration and defence services
53	80	Education services
54	85	Health and social work services
55	90	Sewage and refuse disposal services, sanitation and similar services
56	91	Membership organisation services n.e.c.
57	92	Recreational, cultural and sporting services
58	93	Other services
59	95	Private households with employed persons

Source: own elaboration from WIOD database.

Appendix 5. COMEXT products considered

Num.	COMEXT code, Product	Num.	COMEXT code, Product
1	1511 fresh and preserved meat (except poultry)	47	1822 outerwear
2	1512 fresh and preserved poultry meat	48	1823 underwear
3	1513 meat and poultry meat products	49	1824 other wearing apparel and accessories n.e.c.
4	1520 processed and preserved fish and fish products	50	1830 furs; articles of fur
5	1531 processed and preserved potatoes	51	1910 leather
6	1532 fruit and vegetable juices	52	1920 luggage, handbags and the like; saddlery and harness
7	1533 processed and preserved fruit and vegetables n.e.c	53	1930 footwear
8	1541 crude oil and fats	54	2010 wood, sawn, planed or impregnated
9	1542 refined oils and fats	55	2020 veneer sheets; plywood, laminboard, particle board, fibre board and other panels and boards
10	1543 margarine and similar edible fats	56	2030 builders' joinery and carpentry, of wood
11	1551 dairy products	57	2040 wooden containers
12	1552 ice cream and other edible ice	58	2051 other products of wood
13	1561 grain mill products	59	2052 articles of cork, straw and plaiting
14	1562 starches and starch products	60	2111 pulp
15	1571 prepared animal feeds for farm animals	61	2112 paper and paperboard
16	1572 prepared pet food	62	2121 corrugated paper and paperboard and containers of paper and paperboard
17	1581 bread, fresh pastry goods and cakes	63	2122 household and toilet paper and paper products
18	1582 rusks and biscuits; preserved pastry goods and cakes	64	2123 paper stationery
19	1583 sugar	65	2124 wallpaper
20	1584 cocoa; chocolate and sugar confectionery	66	2125 other articles of paper and paperboard n.e.c.
21	1585 macaroni, noodles, couscous and similar farinaceous products	67	2211 books
22	1586 coffee and tea	68	2212 newspapers, journals and periodicals, appearing at least four times a week
23	1587 condiments and seasonings	69	2213 newspapers, journals and periodicals, appearing less than four times a week
24	1588 homogenised food preparations and dietetic food	70	2214 sound recordings
25	1589 other food products	71	2215 postcards, greeting cards, pictures and other printed matter
26	1591 distilled alcoholic beverages	72	2222 printing services n.e.c.
27	1592 ethyl alcohol	73	2224 composition and plate-making services
28	1593 wines	74	2310 coke oven products
29	1594 cider and other fruit wines	75	2320 refined petroleum products
30	1595 other non-distilled fermented beverages	76	2330 nuclear fuel
31	1596 beer made from malt	77	2411 industrial gases
32	1597 malt	78	2412 dyes and pigments
33	1598 mineral waters and soft drinks	79	2413 other basic inorganic chemicals
34	1600 tobacco products	80	2414 other basic organic chemicals
35	1710 textile yarn and thread	81	2415 fertilizers and nitrogen compounds
36	1720 textile fabrics	82	2416 plastics in primary forms
37	1740 made-up textile articles, except apparel	83	2417 synthetic rubber in primary forms
38	1751 carpets and rugs	84	2420 pesticides and other agro-chemical products
39	1752 cordage, rope, twine and netting	85	2430 paints, varnishes and similar coatings, printing ink and mastics
40	1753 nonwovens and articles made from nonwovens, except apparel	86	2441 basic pharmaceutical products
41	1754 other textiles n.e.c.	87	2442 pharmaceutical preparations
42	1760 knitted or crocheted fabrics	88	2451 glycerol, soap and detergents, cleaning and polishing preparations
43	1771 knitted and crocheted hosiery	89	2452 perfumes and toilet preparations
44	1772 knitted and crocheted pullovers, cardigans and similar articles	90	2461 explosives
45	1810 leather clothes	91	2462 glues and gelatines
46	1821 work wear	92	2463 essential oils

Source: own elaboration from COMEXT database.

Appendix 6. (Continuation) COMEXT products considered

Num.	COMEXT code, Product	Num.	COMEXT code, Product
93	2464 photographic chemical material	141	2745 other non-ferrous metal products
94	2465 prepared unrecorded media	142	2811 metal structures and parts of structures
95	2466 other chemical products n.e.c.	143	2812 builders' carpentry and joinery of metal
96	2470 man-made fibres	144	2821 tanks, reservoirs and containers of metal
97	2511 rubber tyres and tubes	145	2822 central heating radiators and boilers
98	2512 retreaded pneumatic tyres, of rubber	146	2830 steam generators (except central heating hot
99	2513 other rubber products	147	2861 cutlery
100	2521 plastic plates, sheets, tubes and profiles	148	2862 tools
101	2522 packaging products of plastics	149	2863 locks and hinges
102	2523 builder's ware of plastic	150	2871 steel drums and similar containers
103	2524 other plastic products	151	2872 light metal containers
104	2611 flat glass	152	2873 wire products
105	2612 shaped and processed flat glass	153	2874 fasteners, screw machine products, chain and springs
106	2613 hollow glass	154	2875 other fabricated metal products n.e.c.
107	2614 glass fibres	155	2911 engines and turbines except aircraft, vehicle and cycle engines
108	2615 other glass, processed, including technical glassware	156	2912 pumps and compressors
109	2621 ceramic household and ornamental articles	157	2913 taps and valves
110	2622 sanitary ceramic fixtures	158	2914 bearings, gears, gearing and driving elements
111	2623 ceramic insulators and insulating fittings	159	2921 furnaces and furnace burners
112	2624 technical ceramic wares	160	2922 lifting and handling equipment
113	2625 ceramic articles n.e.c.	161	2923 non-domestic cooling and ventilation equipment
114	2626 refractory ceramic goods	162	2924 other general purpose machinery n.e.c.
115	2630 ceramic tiles and flags	163	2931 agricultural tractors
116	2640 bricks, tiles and construction products, in baked clay	164	2932 other agricultural and forestry machinery
117	2651 cement	165	2940 machine-tools
118	2652 lime	166	2941 portable hand held power tools
119	2653 plaster	167	2942 other metalworking machine tools
120	2661 concrete products for construction purposes	168	2943 other machine tools n.e.c.
121	2662 plaster products for construction purposes	169	2951 machinery for metallurgy
122	2663 ready-mixed concrete	170	2952 machinery for mining, quarrying and construction
123	2664 mortars	171	2953 machinery for food, beverage and tobacco processing
124	2665 articles of fibre cement	172	2954 machinery for textile, apparel and leather production
125	2666 other articles of plaster, concrete or cement	173	2955 machinery for paper and paperboard production
126	2670 monumental or building stone and articles thereof	174	2956 other special purpose machinery n.e.c.
127	2681 abrasive products	175	2960 weapons and ammunition
128	2682 other non-metallic mineral products n.e.c.	176	2971 electric domestic appliances
129	2710 basic iron and steel and ferro-alloys (ecsc)	177	2972 non-electric domestic appliances
130	2721 tubes and tube fittings, of cast iron	178	3001 office machinery and parts thereof
131	2722 steel tubes and steel tube fittings	179	3002 computers and other information processing equipment
132	2731 cold drawn products	180	3110 electric motors, generators and transformers
133	2732 cold-rolled of narrow strips	181	3120 electricity distribution and control apparatus
134	2733 cold formed or folded products of iron, non-alloy steel or stainless steel	182	3130 insulated wire and cable
135	2734 wire	183	3140 accumulators, primary cells and primary batteries
136	2735 ferro-alloys (non-ecsc) and other iron and steel n.e.c.	184	3150 lighting equipment and electric lamps
137	2741 precious metals	185	3161 electrical equipment for engines and vehicles n.e.c.
138	2742 aluminium and aluminium products	186	3162 other electrical equipment n.e.c.
139	2743 lead, zinc and tin and products thereof	187	3210 electronic valves and tubes and other electronic components
140	2744 copper products	188	3220 television and radio transmitters, apparatus for line telephony and telegraphy

Source: own elaboration from COMEXT database.

Appendix 5. (Continuation) COMEXT products considered

Prod. Num.	COMEXT code, Product	Prod. Num.	COMEXT code, Product
189	3230 television and radio receivers, sound or video recording or reproducing apparatus and associated goods	204	3550 other transport equipment n.e.c.
190	3310 medical and surgical equipment and orthopaedic appliances	205	3611 chairs and seats
191	3320 instruments and appliances for measuring, checking, testing, navigating and other purposes	206	3612 other office and shop furniture
192	3340 optical instruments and photographic equipment	207	3613 kitchen furniture
193	3350 watches and clocks	208	3614 other furniture
194	3410 motor vehicles	209	3615 mattresses
195	3420 bodies (coachwork) for motor vehicles; trailers and semi-trailers	210	3621 coin and medals
196	3430 parts and accessories for motor vehicles and their engines	211	3622 jewellery and related articles n.e.c.
197	3511 ships	212	3630 musical instruments
198	3512 pleasure and sporting boats	213	3640 sports goods
199	3520 railway and tramway locomotives and rolling stock and parts thereof	214	3650 games and toys
200	3530 aircraft and spacecraft	215	3661 imitation jewellery
201	3541 motorcycles	216	3662 brooms and brushes
202	3542 bicycles	217	3663 other manufactured goods n.e.c.
203	3543 invalid carriages		

Source: own elaboration from COMEXT database.

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Appendix 6. Deflators.

		AUS	BRA	CAN	CHN	IDN	IND	JPN	KOR	MX	RUS	TUR	TWN	USA	ROW
15	Food products and beverages	1.3	2.1	0.6	0.8	2.3	1.0	0.4	0.6	1.0	2.2	0.9	1.5	1.1	1.3
16	Tobacco products*	1.0	3.0	0.6	0.7	4.9	3.8	1.8	1.3	0.6	1.3	0.9	1.0	1.1	2.9
17	Textiles	1.0	1.7	2.1	3.0	3.7	2.4	0.7	1.8	1.7	2.9	2.1	2.2	1.2	2.9
18	Wearing apparel	1.0	1.6	0.6	2.2	1.5	2.1	0.3	2.0	0.9	1.2	1.4	2.5	1.0	1.9
19	Leather and leather products	3.5	1.8	1.9	5.3	2.1	2.2	0.5	1.3	1.6	2.9	2.4	2.8	2.1	2.1
20	Wood and products of wood and cork	1.1	1.0	1.2	1.2	0.8	1.0	0.3	0.4	0.4	1.8	0.8	0.5	0.8	1.3
21	Pulp, paper and paper products	1.0	1.1	0.9	0.7	0.8	0.8	0.2	0.6	1.0	1.0	1.1	0.4	0.7	0.9
22	Printed matter and recorded media	0.8	0.7	0.6	2.7	3.7	3.2	0.4	2.0	0.5	1.0	2.1	1.1	0.8	1.6
23	Coke, refined petroleum products	5.3	1.4	1.6	0.6	0.9	0.9	0.9	0.9	8.7	1.1	0.8	1.0	1.5	1.0
24	Chemicals, chemical products	0.9	3.2	1.2	2.3	7.4	2.2	0.4	2.0	2.1	3.0	2.4	1.5	0.8	1.4
25	Rubber and plastic products	0.7	1.0	1.1	1.9	1.5	1.8	0.6	1.1	0.9	0.9	1.4	1.2	0.6	1.4
26	Other non-metallic mineral products	0.5	1.3	1.5	2.7	2.1	1.6	0.3	0.5	1.1	2.7	1.7	1.5	0.4	2.2
27	Basic metals	0.4	0.9	0.2	1.4	0.4	1.4	0.5	0.7	1.0	1.1	1.6	1.1	0.7	0.6
28	Fabricated metal products	0.8	1.6	0.9	2.6	1.9	2.5	0.8	1.8	1.2	2.5	2.1	2.3	0.5	1.2
29	Machinery and equipment n.e.c.	0.9	1.9	0.7	2.9	2.3	2.4	0.9	1.9	1.1	2.0	2.5	2.0	0.8	1.0
30	Office machinery and computers	0.4	0.9	0.6	1.4	3.1	2.4	0.7	0.7	0.7	0.6	1.3	0.9	0.8	0.9
31	Electrical machinery	0.4	2.4	0.4	2.2	2.0	2.4	0.6	1.2	0.8	2.0	2.2	0.9	0.4	1.1
32	Radio, television and comm. eq.	1.4	2.7	0.7	2.9	1.5	4.5	1.5	1.1	0.8	1.7	2.2	1.4	1.3	2.2
33	Medical and optical instruments	0.6	2.5	1.0	8.4	1.6	3.7	1.0	2.6	1.6	0.4	6.2	3.1	0.8	1.0
34	Motor vehicles, trailers	0.7	1.2	1.0	2.7	1.4	1.6	0.9	1.5	1.0	1.7	1.2	1.5	0.9	1.3
35	Other transport equipment	1.7	1.0	1.4	1.8	3.6	2.5	1.1	0.3	2.6	5.1	1.4	1.5	1.3	0.7
36	Furniture; other manufactured goods	0.2	13.4	0.6	2.5	2.4	1.4	0.6	1.6	1.8	1.1	1.8	1.9	1.1	1.7

Source: own elaboration on COMEXT and WIOD databases.

Non-EU countries: AUS: Australia; BRA: Brazil; CAN: Canada; CHN: China; IDN: Indonesia; IND: India; JPN: Japan; KOR: Korea; MEX: Mexico; RUS: Russia; TUR: Turkey; TWN: Taiwan; USA: United States; ROW: Rest of the World.

* The category "tobacco products" has been adjusted using additional more disaggregated data from the COMEXT database "EU Trade Since 1988 By SITC", following the nomenclature correspondence provided by Eurostat in the database RAMON available at http://ec.europa.eu/eurostat/ramon/relations/index.cfm?TargetUrl=LST_REL.

References

American House of Representative, 2009. American Clean Energy and Security Act H.R.2454. Available at http://www.gpo.gov/fdsys/pkg/BILLS-111hr2454ih/pdf/BILLS-111hr2454ih.pdf

Arto I, Roca J, Serrano M. 2014. Measuring emissions avoided by international trade: Accounting for price differences. Ecological Economics, 97, 93-100.

Atkinson et al 2011_Trade in virtual carbon_ Empirical results and implications for policy

Böhringer et al 2012_Alternative designs for tariffs on embodied carbon A global cost-effectiveness analysis

Burniaux et al, 2010. Is there a case for carbon-based border tax adjustment? An applied general equilibrium analysis (OECD WP)

Dissou and Eyland _2011_Carbon-control-policies-competitiveness-and-border-tax-adjustments

Eurostat. 2002. "Statistical Classification of Economic Activities in the European Community, Rev. 1.1 (2002) (NACE Rev. 1.1)." Available at: http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_CLS_DLD&StrN om=NACE_1_1.

—. 2008. "Statistical Classification of Products by Activity in the European Economic Community." Available at: http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=CPA_2008&StrLanguageCode=EN&IntPcKey=&StrLayoutCode=HIERARCHIC&CFID=1319672&CFTOKEN=f7fdee4196b6231d-B5DE2A71-E2C1-E0AE-1A9F2597913602D5&jsessionid=1f518eb6f275b6ehttp://ec.europa.eu/eu.

—. 2014. "Euro/ECU exchange rates – annual data." Available at: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ert_bil_eur_a&lang=en

—. 2015. "EU Trade since 1988 By CPA_2002 (DS-056992)." Available at: http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do

Elliott 2012_Unilateral Carbon Taxes, Border Tax Adjustments, and Carbon Leakage

—, 2011. Proposal for a Council Directive amending Directive 2003/96/EC restructuring the Community framework for the taxation of energy products and electricity. COM (2011) 169, March 8. Brussels.

Art. 10b of Directive 2009/29/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading scheme of the Community

Ghosh_2012_Border-tax-adjustments-in-the-climate-policy-context-CO2-versus-broad-based-GHG-emission-targeting

Hillman2013_CHANGING CLIMATE FOR CARBON TAXES

Horn Sapir 2013_Can border carbon taxes fit into the global trade regime

Houser et al 2008_leveling_the_carbon_playing_field

Kuik, Hofkes, 2009. Border adjustment for European emission trading: competitiveness and carbon leakage (Energy Policy)

Lin, Li, 2011. Impacts of carbon motivated border tax adjustments on competitiveness across regions in China (Energy)

Lockwood Whalley2010_Carbon-motivated Border Tax Adjustments Old Wine in Green Bottles

(Markusen 1975, International externalities and optimal tax structures)

Mathiesen, Maestad, 2002. Climate policy and the steel industry: achieving global emission reductions by an incomplete climate agreement

Mattoo et al., 2009, Reconciling climate change and trade policy (WB WP)

Schenker_et_al 2012_Taxing carbon along the value chain

WIOD. 2012. "Emission relevant energy use by sector and emergy commodity". World Input Output Database project (available at: http://www.wiod.org/database/iot.htm).

WIOD. 2013. "World input output table at current prices". World Input Output Database project (available at: http://www.wiod.org/database/iot.htm).

WTO 2009, trade and climate change; a report by the United Nations Environmental Program and the World Trade Organization. Geneva.

Table 3. CBTA cost for each EU country as a percentage of the value of manufactured and total import from non-EU countries

	Embodied emissions				Avoided emission (defl)			
	Manufact. import		Total import		Manufact. import		Total import	
Austria	2.6	[16]	1.4	[15]	1.2	[22]	0.6	[18]
Belgium	2.6	[11]	1.5	[13]	1.3	[18]	0.7	[15]
Bulgaria	2.8	[7]	1.5	[14]	1.5	[4]	0.8	[9]
Cyprus	2.8	[6]	1.7	[8]	1.4	[7]	0.9	[6]
Czech republic	2.7	[9]	1.9	[4]	1.1	[26]	0.8	[11]
Germany	2.5	[18]	1.8	[6]	1.2	[21]	0.8	[7]
Denmark	2.4	[23]	1.1	[23]	1.3	[13]	0.6	[21]
Spain	2.6	[17]	1.4	[16]	1.4	[6]	0.8	[13]
Estonia	3.0	[4]	2.2	[2]	1.5	[5]	1.1	[1]
Finland	3.1	[3]	1.3	[18]	1.3	[12]	0.6	[22]
France	2.5	[21]	1.6	[11]	1.3	[16]	0.8	[10]
Uk	2.4	[25]	1.3	[17]	1.2	[19]	0.7	[17]
Greece	2.6	[12]	1.3	[20]	1.2	[20]	0.6	[20]
Hungary	2.6	[14]	1.5	[12]	1.2	[23]	0.7	[16]
Ireland	2.1	[27]	0.5	[26]	1.0	[27]	0.3	[26]
Italy	2.7	[8]	1.2	[21]	1.3	[10]	0.6	[19]
Lithuania	3.3	[2]	1.3	[19]	1.8	[1]	0.7	[14]
Luxembourg	2.4	[26]	0.1	[27]	1.1	[25]	0.1	[27]
Latvia	3.6	[1]	2.3	[1]	1.6	[2]	1.0	[3]
Malta	2.4	[24]	1.8	[5]	1.3	[11]	1.0	[4]
Netherlands	2.4	[22]	0.9	[25]	1.3	[14]	0.5	[25]
Poland	2.6	[13]	1.6	[10]	1.3	[15]	0.8	[12]
Portugal	2.6	[15]	1.0	[24]	1.4	[9]	0.5	[24]
Romania	2.9	[5]	1.6	[9]	1.6	[3]	0.9	[5]
Slovakia	2.5	[20]	1.8	[7]	1.2	[24]	0.8	[8]
Slovenia	2.7	[10]	2.0	[3]	1.4	[8]	1.0	[2]
Sweden	2.5	[19]	1.1	[22]	1.3	[17]	0.5	[23]

Source: own elaboration.

*Countries ranking: [1] is the most affected country, [27] is the less affected.