Border carbon adjustment and potential trade retaliation: an evaluation with MIRAGE-e

Jean Fouré[1] Houssein Guimbard[2] Stéphanie Monjon[3]

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Abstract

Recently, carbon leakage risks have been seriously examined in the framework of the European Emission Trading Scheme (EU ETS). Since 2005, this system caps emissions of highly emissive European companies. But some of these companies are significantly exposed to international competition. Several Member States, in particular France, have proposed to impose a border carbon adjustment (BCA) to imports of the products covered by the EU ETS. However, as a trade measure, a BCA may be contested by a World Trade Organization member under its dispute settlement mechanism and may lead to trade retaliation from some trade partners. While the economic impacts of border carbon adjustment measures have been addressed in several papers, we are not aware of any study that assesses the implications of trade retaliation if the BCA is deemed illegal. The aim of this paper is to analyze the efficiency, in terms of carbon leakage limitation, of a BCA in complement to the EU ETS, but also to evaluate the cost of possible trade retaliation due to the implementation of the trade measure.

Keywords: Emission trading scheme, border carbon adjustment, trade retaliation

JEL Classification: C68, F18, Q3

[1] CEPII (jean.foure@cepii.fr)
[2] CEPII (houssein.guimbard@cepii.fr)
[3] PSL*, University Paris-Dauphine (LEDa-CGEMP), CEPII and CIRED (stephanie.monjon@dauphine.fr)

1. Introduction

Several countries are experiencing an increased political pressure for some form of border carbon adjustment (BCA) to complement a stringent climate policy. This would level the playing field between domestic producers and foreign producers who face little or no constraint on their greenhouse gas (GHG) emissions. Arguments that justify such a trade measure generally refer to competitiveness concerns and/or to the weakening of environmental efficiency of the climate policies. Indeed, if a firm supports higher costs in its home country, it may struggle to compete and move offshore or lose its business to offshore companies. The domestic industry would then lose market share in both domestic and foreign markets, resulting in job losses at home and an increase in GHG emissions abroad, i.e. carbon leakage.[4]

The carbon leakage risks have been seriously examined in the framework of the EU Emission Trading Scheme (ETS). Since 2005, this system caps emissions of highly emissive European companies. But some of these companies are significantly subject to international competition. From 2013 onwards, the "sectors or subsectors which are exposed to a significant risk of carbon leakage"[5] will continue to benefit from a constant free allowance allocation, while other sectors will receive a less and less important free allowance allocation or will have to buy all the allowances they need. Few Member States, in particular France, have repeatedly proposed to impose also a BCA to imports of the products covered by the EU ETS. However, as a trade measure, a BCA may be contested by a World Trade Organization (WTO) member under its dispute settlement mechanism. Even if several recent analyses (Ismer and Neuhoff, 2007; Pauwelyn, 2007; Eichenberg, 2010), including a recent report from WTO-UNEP (2009), conclude that such a measure may be WTO-compatible, the possibility of dispute settlement and trade retaliation remains serious. In 2010, the Indian Environment Minister Jairam Rames stated that "India [would] bring a WTO challenge against any "carbon taxes" that rich countries impose on Indian imports" (ICTSD, 2010). The conflict opposing EU and a broad coalition of countries, including Russia, India, the United States and China, on the inclusion into the EU ETS of all the airlines operating in the EU perfectly illustrates this risk (Reuters, 2011).

While the economic impacts of border carbon adjustment measures have been addressed in several papers, we are not aware of any study that assesses the implications of trade retaliation if the BCA is deemed illegal. The aim of the paper is to analyze the efficiency, in particular in terms of carbon leakage limitation, of a BCA in complement to the EU ETS, but also to evaluate the cost of possible trade retaliation due to the implementation of such a trade measure.

The analysis is based on the model MIRAGE-e, the energy-oriented version of CEPII's global CGE model, MIRAGE. A first scenario attempts to represent the commitments taken in the world in terms of greenhouse gas (GHG) emissions reductions. This scenario models an increasing constraint on GHG emissions of the highly emissive industrial sectors in the EU up to 2025 based on the decision taken by European Parliament and Council in 2009, including the integration of the aviation sector from 2012 (EU, 2009). The emission reductions applied in the non-ETS sectors and in the rest of the world are consistent with the pledges taken in the Copenhagen and Durban Agreements (Delink et al.,

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[4] Carbon leakage is defined as the increase in emissions in non-abating regions as a reaction to the reduction of emissions in abating regions.
[5] Article 10a-12 (EU, 2009).

2010). A second scenario encompasses the implementation of a BCA to imports of the products covered by the EU ETS. Like the EU producers, the foreign producers must surrender allowances equal to the emissions linked to the production (and not the transportation) of the imported products and receives a free allowance allocation. A last scenario assumes that EU's main trade partners bring a WTO challenge against the BCA and apply some trade retaliation, modeled as an increase of custom duties, compatible with the WTO framework.

Section 2 briefly discusses the rationale of a BCA as well as the possibility of trade retaliation of such a measure. Section 3 explains the methodology used and the policy simulations. Results are discussed in Section 4. Section 5 concludes.

2. A case for trade measure

Some politicians, economists and environmentalists have periodically promoted BCAs, while others have underlined the risk of such trade measure. For instance, Stiglitz has called for a carbon tax or trade measures against countries not cutting carbon emissions (Stiglitz, 2006). Several policy projects on the implementation of a carbon tax or an ETS targeting the industry discussed, even planed, the implementation of such trade measure. In the US, the Waxman-Markey bill, which was adopted by the House of Representatives in 2009 (but not by the Senate), planed to set up an "international reserve allowance program." From 2020 onwards, imports in a covered sector would have been prohibited unless the importer has obtained an "appropriate" amount of emission allowances from the international reserve allowance program (van Asselt and Brewer, 2010). However, other experts underline the high potential of protectionist use of BCA and the induced risk to threaten the good will in international climate negotiations if implemented by some developed countries.[6]

The aim of a BCA is essentially to level the playing field by imposing the same or similar costs to foreign producers as domestic climate policy imposes on domestic production. The efficiency of such measure has been evaluated in many papers. Several focus on trade measures in the light of the Kyoto protocol, assuming countervailing carbon levies for all the sectors of the countries reducing their greenhouse gas emissions (GHG). For example, Babiker and Rutherford (2005) find that such BCA can substantially reduce the welfare losses for the coalition members by shifting a great part of the carbon policy burden to the non-coalition members. More recently, the focus has moved towards the sectors covered by the EU ETS, and more precisely for those exposed to the international competition. Alexeeva-Talebi et al. (2008a) show that BCAs efficiently mitigate the production decline caused by a unilateral European climate policy on energy-intensive and export-oriented industries, especially if applied both to imports and exports, and if based on foreign rather than on EU average emission factors. This decline reaches 1.69% in the EU27 without a BCA, 1.23% with a BCA on imports only, 0.58% with a BCA on exports only and 0.11% with a BCA on both, if EU emission factors are used. With foreign emission factors, EU output in the sectors covered by the BCA actually increases since EU average emission factors are lower than foreign ones. Manders and Veenendaal (2008) also examine whether a BA mitigates the impacts of climate policy, making use of the general equilibrium model WorldScan. They find a rather low leakage rate with a unilateral climate policy: 3.3%.[7] This ratio becomes negative with an import BCA (-1.4%), with an export BCA (-1.3%) and even more with a BCA on both imports and exports (-2.8%), even though the EU average emission factors are used to

[6] See Droege et al. (2009) for a discussion on the pros and cons of a BCA.
[7] The carbon leakage rate is defined as the increase of emissions in non-coalition members (with respect to the baseline) as a percentage of the emission reduction by the coalition members (with respect to the baseline).

calculate the BCA.[8] Nevertheless, this limitation of the carbon leakage comes at the expense of the sectors that do not benefit of the BCA, they are also included in the permit system or not (Manders and Veenendaal, 2008; Alexeeva-Talebi et al., 2008a and 2008b).

Risk of a WTO challenge

As a trade measure, a BCA may be contested by a WTO member. Any measure with a serious trade impact is likely to trigger a WTO complaint. Recent law analysis have questioned this position and concluded that, under some conditions, such a measure may be WTO-compatible (Ismer and Neuhoff, 2007; Pauwelyn, 2007; WTO-UNEP, 2009; Eichenberg, 2010). Generally, two options are examined: firstly, compatibility with the GATT general regime, and then - if the BCA has not been judged compatible with the general regime - a possible recourse to the environmental exception rule Article XX. WTO-compatibility depends on the design of the BCA, but also on the manner in which it is implemented, especially for the 'Article XX' option.

Nevertheless, whether a BCA would be permitted under WTO rules remains uncertain and the risk of trade retaliation cannot be ruled out definitively. Consequently, it is relevant to take into account this risk and to evaluate the cost of trade retaliation. To our knowledge, such analysis has never been considered.

3. Methodology

3.1. The MIRAGE-e model

MIRAGE-e is adapted from the multi-sectoral and multi-regional computable general equilibrium (CGE) MIRAGE model (Bchir et al., 2002; Decreux and Valin, 2007), which has been developed and extensively used to assess trade liberalization and agricultural policy scenarios (e.g., Bouët et al., 2005, 2007). MIRAGE is built on sequential dynamic recursive set-up, used to evaluate a long-term path for the world economy, taking as given stock variables such as labor force or GDP. MIRAGE-e proposes an improved energy modeling and its dynamics rely on a new baseline built upon the MaGE model (Macroeconometrics of the Global Economy, Fouré et al., 2012). The detailed MIRAGE-e framework is described in Fontagné et al. (2012).

Each sector is modeled as a representative firm, exhibiting constant returns to scale, whose production function combines value-added and intermediate consumption in fixed shares. Value-added is a bundle of imperfectly substitutable primary factors: capital, skilled labor, unskilled labor, land, natural resources and energy.

All primary factors endowments are supposed to be fully employed and their growth rates are set exogenously taken from the MaGE projections. Installed capital stock is assumed to be immobile (sector-specific), while investment, which represents the long run adjusting possibilities of a capital market, is allocated across sectors (perfect mobility) according to their rate of return to capital. Skilled labor is perfectly mobile across sectors, while unskilled labor is imperfectly mobile between agricultural and other sectors. Land is assumed to be imperfectly mobile between agricultural sectors and natural resources are sector-specific. Consumption of the five energy goods by firms is aggregated in a single bundle which mainly substitutes with capital. This energy aggregate is subject to specific productivity improvements resulting from the growth model MaGE.

[8] Negative leakage means that both domestic and foreign emissions decrease due to the actions taken by the ETS region.

In the energy producing sectors, substitutions between energies are allowed only for electricity generation. Moreover, the energy productivity does not improve in these sectors.

The demand side is modeled through a representative consumer from each region that maximizes its intra-temporal utility function under its budget constraint. This unique agent, which includes households and government, saves a fixed part of his income and the rest is spent on goods, while respecting levels of minimal consumption.

3.2. Aggregation of regions and sectors

MIRAGE-e data for the base year 2004 are taken from the GTAP-7 database that contains integrated data on bilateral trade flows and input-output accounts for 57 sectors and 113 countries and regions. We also use two GTAP additional databases for year 2004 on energy consumption (in tons of oil equivalent) and CO_2 emissions (in tons of CO_2-energy) which are consistent with the standard GTAP database.

The GTAP dataset provides a large number of countries, covering the whole world. Table 1 describes how GTAP sectors and regions are aggregated in the present study. The geographical aggregation used (18 countries) is precise enough to represent the emission reduction commitments taken in the 2010 Durban Agreement. Besides, France is considered explicitly.

Designing an aggregation that perfectly isolates the sectors concerned with the EU ETS is not easy task. Indeed, requirements imposed by the data sources (57 sectors in GTAP, corresponding to more than 5,000 products) make it difficult to represent a detailed proposition. For instance, the sector "Paper products, publishing" includes some activities whose emissions due to the fossil fuel combustion are not subject to the EU-ETS, like the publishing activity. Taking this into consideration, we identify seven sectors in GTAP that could correspond to the EU-ETS.

MIRAGE-e also distinguishes three additional energy sectors (coal, oil and gas). The other sectors are aggregated in six large sectors: an extraction sector, two agriculture sectors, a rest of industry sector and two services sector.

Table 1 - Overview of regions and sectors in MIRAGE-e

Regions	Sectors
Developed countries	**EU ETS sectors**
France	Paper products. publishing (ppp),
EU27	Petroleum. coal products (p_c),
EFTA	Chemical.rubber.plastic prods (crp),
USA	Mineral products nec (nmm),
Canada	Ferrous metals (i_s),
Japan	Metals nec (nfm),
Oceania	Electricity (ely).
Developing countries	**Energy sectors**
Rest of Europe	Coal (coa),
Brazil	Oil (oil),
Russia	Gas (gas and gdt).
India	**Agriculture**
China (China and Hong Kong)	Crops[c]
South Africa	Livestock[d]
Oil producers[a]	**Industry**
Other Latin America	Other extraction (omn)
Other south-east Asia	Rest of industry[e]
LDC[b]	**Services**
Other	Transports[f]
	Services[g]

[a] Indonesia, Venezuela, Rest of Western Asia, Iran, Islamic Republic of, Rest of North Africa, Nigeria.
[b] Cambodia, Lao People's Democratic Republic, Rest of Southeast Asia, Bangladesh, Rest of South Asia, Senegal, Rest of Western Africa, Central Africa, South-Central Africa, Ethiopia, Madagascar, Malawi, Mozambique, Tanzania, Uganda, Zambia, Rest of Eastern Africa.
[c] Paddy rice (pdr), Wheat (wht), Cereal grains nec (gro), Vegetables. fruit. nuts (v_f), Oil seeds (osd), Sugar cane. sugar beet (c_b), Plant-based fibers (pfb), Crops nec (ocr).
[d] Cattle.sheep.goats.horses (ctl), Animal products nec (oap), Raw milk (rmk), Wool. silk-worm cocoons (wol), Forestry (frs), Fishing (fsh).
[e] Meat: cattle.sheep.goats.horse (cmt), Meat products nec (omt), Vegetable oils and fats (vol), Dairy products (mil), Processed rice (pcr), Sugar (sgr), Food products nec (ofd), Beverages and tobacco products (b_t), Textiles (tex), Wearing apparel (wap), Leather products (lea), Wood products (lum), Motor vehicles and parts (mvh), Transport equipment nec (otn), Electronic equipment (ele), Machinery and equipment nec (ome), Manufactures nec (omf).
[f] Transport nec (otp), Sea transport (wtp), Air transport (atp),
[g] Water (wtr), Construction (cns), Trade (trd), Communication (cmn), Financial services nec (ofi), Insurance (isr), Business services nec (obs), Recreation and other services (ros), PubAdmin/Defence/Health/Educat (osg), Dwellings (dwe).

3.3. The scenarios

The effects of climate policy depend on the underlying baseline. All counterfactual analyses depart from a scenario without climate policy called a Business-As-Usual (BAU) scenario. The aim of this BAU scenario is to build a framework to which will be compared our set of simulations. Then a scenario called “ETS” represents a stylized version of the emission reduction commitments made in the Copenhagen and Durban Agreements and of the decisions taken by the EU. After 2020, it is assumed that emissions reductions are strengthened following the same trend as during the previous decade. The scenario with a BCA differs from the reference scenario by assuming the implementation of a BCA to imports of the products covered by the EU ETS. The scenario with trade retaliation is similar to the previous scenario but assumes that the main trade partners of the EU implements some trade retaliation due to the European BCA.

3.3.1. The reference scenario

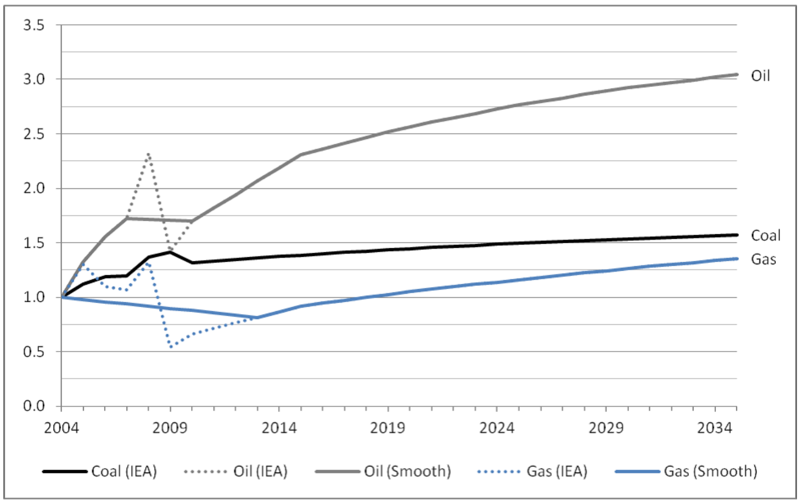
In the BAU scenario, GDP is set exogenously from the baseline growth trajectory produced with the model MaGE.[9] The productivity in each sector is exogenous as well and comes from Fontagné et al.

[9] The detailed methodology and results of the growth model baseline is described in Fouré et al. (2012).

(2012).[10] Lastly, the level of total factor productivity (TFP) adjusts such that the GDP growth rate in MIRAGE-e matches the baseline growth trajectory.

In the reference scenario, prices of fossil energy (coal, oil and gas) are set exogenous and taken from the IEA (2011). Local natural resources adjust in order to match these fossil fuel price targets. However, over the past 8 years, energy prices have been very volatile, and the model is not able to respond to such large variations. We therefore smooth the prices from 2005 to 2012, as shown in Figure 1.

Figure 1 – World primary energy prices in the reference scenario (2004=1)



Sources: IEA(2011) and own computations.

Contrary to the BAU scenario, in simulations, GDP becomes endogenous, whereas the level of TFP is fixed to the one computed in the reference case. Moreover, world primary energy prices become endogenous, while the reserves are supposed to remain at their reference level.

In the scenarios, the energy productivity, as well as savings rate, total and active population, follow the same trajectory as in the BAU scenario.

3.3.2. The pre-experiment scenario (ETS scenario)

3.3.2.1. The European Union and EFTA countries

The emission reductions

The EU sets its emission target for 2020 at 20% below 1990 levels which represents a emission reduction of -14% between 2005 and 2020. This last global emission reduction objective can be decomposed into a -21% reduction in the ETS sectors and a -10% reduction in the non-ETS sectors in the EU (Climate Action, 2011).

Norway, Liechtenstein and Iceland have implemented an ETS and have linked it to the EU ETS. Switzerland launched its ETS in 2008. Ongoing negotiations have for objective to link it with the EU ETS. In MIRAGE-e, EFTA is considered as a single region (containing four countries). We assume that their ETS is linked to the EU ETS since 2008 and has the same objective of emissions reduction as in the EU ETS. For the non-ETS sectors, the same objective as in the EU is applied.

[10] See Fontagné et al (2012) for the details on the evaluation of the TFP in each sector. Note that the Agricultural productivity (for Crops and Livestock) has required a specific treatment which differs from the method used for TFP in industry and services.

In the model, the representation of the ETS corresponds to a carbon tax introduced at the level of every energy consumption by firms. The additional cost is included in the price on the basis of the carbon emissions content of the good (after burning). The level of the tax then adjusts endogenously, such that the regional cap is respected and the tax represents the equilibrium price of carbon.

This modeling is equivalent to a cap and trade system as long as (i) the carbon market is in perfect competition and (ii) the constraint on regional emissions is binding. In the case emissions would not be constrained by the cap, such modeling would imply a negative carbon price and an incentive to pollute. We therefore need to control that the emissions without cap are greater than the level of the cap; otherwise we assume no carbon price.

The use of flexibility

The EU ETS allows for some flexibility among energy-intensive sectors within the EU. We assume that the use of permits from Clean Development Mechanism (CDM) or Joint Implementation (JI) is allowed in the EU ETS but up to the limits (11%) proposed in the Directive 2009/29/EC (Article 11a)[11].

In MIRAGE-e, the use of international credits is modeled as a loosening of the constraint with the availability of a greater number of allowances to the ETS sectors. This implies that the price of the EU allowances and of the international credits is the same.

The allocation mode

During the period 2008-2012, we assume that all the allowances are allocated freely. The quantity of allowances received by each sector corresponds to the share of their emissions in 2004 applied to the cap of each year. The number of allowances received each year is then decreasing for each sector.

During the period 2013-2020, we only distinguish two different categories of activities: the electricity sector which has the obligation to buy all his allowances[13] and the other sectors which are considered exposed to the carbon leakage risk. The latter sectors benefit from a fixed quantity of free allowances during the period 2013-2020. This quantity corresponds to the share of their emissions in 2004 applied to the cap of 2013.

During the period 2021-2025, we assume that the same rule is applied to different sectors but the quantity of allowances allocated to the sectors exposed to the carbon leakage risk is updated. The share of their emissions in 2004 is applied to the cap of 2021 and the number allocated is fixed each year.

The modeling of a fixed amount of free allowances allocated in a CGE model is not straightforward. Indeed the sectors are assumed to be in perfect competition and the production decision of the representative firm is only impacted by variable incentive (like a unitary tax) but not by a a lump sum payment.

The simple framework, described in Appendix A, illustrates how MIRAGE-e integrates free CO_2 allowances allocation using an endogenous production subsidy. It is interesting to note that this production subsidy is not an output-based subsidy: the amount given to the firm is *de facto* independent from output level and does not interfere directly with first order conditions. When encompassing perfect competition, distinguishing between the impacts of such lump-sum transfers to

[11] *"All existing operators shall be allowed to use credits during the period from 2008 to 2020 up to either the amount allowed to them during the period from 2008 to 2012, or to an amount corresponding to a percentage, which shall not be set below 11 %, of their allocation during the period from 2008 to 2012, whichever is the highest." (Article 11a (8))*

[13] The revenues from auctioning emission permits are transferred to the representative consumer of each region.

the firm becomes complicated. In fact, it acts as a subsidy to consumers (both households and firms) by increasing the gap between the price producers obtain from their product and the price consumers pay. The demand function is offset due to the subsidy and the new equilibrium price is higher from the producer's point of view. Nevertheless, the difference does not necessarily equal the amount of the subsidy, meaning that the benefits from the subsidy is shared between producers and consumers.

The inclusion of the aviation sector in the EU ETS

Since 2012, airlines are integrated into the EU ETS. Nevertheless, in the ETS scenario, the aviation sector is not modeled into the EU ETS for two main reasons. First, data on aviation do not allow identifying travels that would be subject to ETS (i.e. departing from or arriving to EU). Secondly, while the airlines can buy the allowances created for the industry and energy sectors for their conformity, the opposite is not possible.

According Boon et al. (2007), the airlines will be at the origin of a high demand of industrial allowances. Therefore, we take into account the impact of the demand of the airlines by reducing the available allowances number to the ETS sectors. The number of allowances bought by the aviation sector is taken from Boon et al. (2007), to which we add the possibility of CDM and JI credits use by the airline (11%).

3.3.2.2. The rest of the world

For the other countries, we assume that the emission reduction commitments taken in the Copenhagen and Durban agreements are applied.[14] Unlike the Kyoto Protocol, the way in which countries report on reductions in emissions that they plan to make is not standardised. Consequently there is a mosaic of different pledges, where procedures (absolute/relative target, reference year etc.) vary widely between countries. Moreover, some pledges correspond to an interval rather than to only one figure. For instance, "China will endeavor to lower its carbon dioxide emissions per unit of GDP by 40-45% by 2020 compared to the 2005 level". Consequently, the evaluations of the Agreement generally distinguish between low and high pledges.

In our simulations only the low pledges are considered. Moreover, the pledges expressed in terms of CO_2 emissions per GDP unit of a specific year, or relatively to the projected emissions in a BAU scenario, are expressed like an absolute cap on emissions based on MIRAGE-e evaluations. Table 2 presents countries' commitments, also translated into our geographical aggregation.

[14] See for instance Stern and Taylor (2010) for a detailed list of the pledges.

Table 2 – Quantitative pledges as of March 2010

Zone	Target year	Pledge	Modality	Equivalent from 2005 emissions
USA	2020	-17%	From 2005 level	-17.0%
Oceania				-16.5%
Australia	2020	-5%	From 2000 level	-14.8%
New Zealand	2020	-10%	From 1990 level	-35.2%
Russian Federation	2020	-15%	From 1990 level	+16.8%
Rest of Europe*				+44.7%
Belarus	2020	-5%	From 1990 level	+40.8%
Croatia	2020	-5%	From 1990 level	-32.4%
Moldova	2020	-25%	From 1990 level	+221.3%
Canada	2020	-17%	From 2005 level	-17.0%
Japan	2020	-25%	From 1990 level	-33.7%
China	2020	-40%	From 2005 intensity	N.A.
India	2020	-20%	From 2005 intensity	N.A.
Brazil	2020	-36%	From BAU	N.A.
South Africa	2025	-30%	From BAU	N.A.
Other Countries**				
Indonesia	2020	-26%	From BAU	N.A.
Mexico	2020	-30%	From BAU	N.A.
Singapore	2020	-16%	From BAU	N.A.
South Korea	2020	-30%	From BAU	N.A.
Kazakhstan	2020	-15%	From 1992 level	N.A.

Notes: * Other countries for the Rest of Europe zone (mainly Albania and Ukraine) did not pledge. The reduction for the whole group is computed with its BAU emissions. Conversions for these countries are based on the emissions level of 1992 (1990 not available).
** These pledges were not implemented in our scenarios because of their being part of much larger regions in the aggregation.
Source: International Energy Agency (2011), World Development Indicators and own computations.

In order to represent these pledges in the model, we assume that these countries will impose a carbon tax to achieve their emissions reduction objective. It concerns all sectors, from 2005 to 2025.

3.3.3. The scenario with a border carbon adjustment (BCA scenario)

The definition of the BCA is based on the propositions which have been made since 2008, above all by France: the BCA is applied only to the imports and it is implemented without removal of the free allowance allocation to the sectors exposed to the risk of carbon leakage. This point is really critical for the legality of the BCA. Indeed, the adjustment is much more difficult to justify under free allocation than under auctioning. Law literature agrees with this conclusion (de Cendra, 2006; van Asselt and Biermann, 2007; Kommerskollegium, 2009).

The definition of other components of the BCA attempts to respect some fundamental principles of the GATT's general regime the most. In particular, the domestic and foreign producers have the same treatment under the EU ETS. Indeed, according to Pauwelyn (2009), carbon equalization measures on imports at the border (a border duty, allowance requirement or performance standard) may be modeled in compliance with WTO non-discrimination rules if the measure does not impose a heavier burden on imported products than on domestic products. Thus, like the EU (and EFTA) producers, the foreign producers must surrender allowances equal to the emissions linked to the production of the imported products and receive a free allowance allocation evaluated in the same manner as for the domestic producers. This differs from what is generally made to evaluate such trade measure. For instance, in Manders and Veenendaal (2008) and Kuik and Hofkes (2010), importers have to pay a carbon tax. Consequently, the impact on the allowance market is less direct than with an 'allowance-based' BCA under which importers are committed to buy some allowances and then influence their price level.

This modeling choice implies adjusting allowances supply in order to match the new field of emissions covered.

The evaluation of the allowances number to surrender and of the free allowance allocation is based on the carbon content of imported products. While European firms included in the EU ETS are obliged to provide their emission level, a similar obligation can hardly be imposed on importers. The use of average emission intensity depending on the origin country can be problematic (Monjon and Quirion, 2010). Generally the law literature concludes that the use of emission intensity based on Best Available Technology (BAT) for importers allows ensuring a more similar treatment, or at least a more favorable treatment of imported (rather than European) products (Ismer and Neuhoff, 2007). The adjustment is only partial then. For the moment, the emission intensity used is the foreign emission intensity but another simulation using emission intensity due to BAT is ongoing.

In the model, BCA is implemented at the level of European importers, as well as the free allocation which consists of a rebate on the tax base. This simple assumption is made possible by the nature of the basis of BCA tax which is the same as tariffs.

3.3.4. The scenario with trade retaliation (TR scenario)

Determining trade retaliation

Similarly to the Hormones Case (Canada-EU-USA) in which the EU has banned the use of hormones in meat production, the BCA concerns both domestic production and imports and could be considered as an obstacle to trade by a panel of potential complainants that experience losses in their exports to the EU. However, though from a legal aspect, any WTO members can take the case to the Dispute Settlement Body (DSB) of the WTO, only large countries have enough financial and human resources to win trade wars (e.g. Breuss, 2003). Thus, we limit the set of such countries to a restricted numbers of large exporters: China, India and the USA[15]. , None of the complainants belongs to bilateral trade agreements with the EU, ensuring that only WTO legal aspects can be used.

Therefore, in TR scenario, each complainant requests the DSB of the WTO to authorize the suspension of the application of Most Favored Nation (MFN) tariffs to the EU and its Member States. This suspension is applied to some trade flows whose the amount equalizes the export losses due to the BCA. Those losses are evaluated as the difference of complainants' exports towards the EU between the BCA scenario and the ETS scenario.[16].

Regarding the design of suspensions, the WTO rules leave most of the decisions to the discretion of the retaliating country (Pauwelyn, 2010). In order to determine the list of products and the magnitude of tariff retaliations, we assume that the goal of those WTO suspensions is not to compensate exporters' losses, but to punish the EU for such policy.[17] Thus, we apply a 100% duty on products we characterize as politically sensitive for the EU[18]. The retaliatory tariff is meant to be prohibitive at the HS6 level. As MIRAGE-e uses an aggregated version of the GTAP 7 database, the average tariff at the sectoral level might be not prohibitive itself, but will be higher in any case.

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[15] Brazil, Japan and Canada raise their exports in those sectors to EU in 2013. We assume thus they will not complain.
[16] China'exports in ETS sectors to the EU decline by 36 millions USD, India by 321 millions USD and the USA by 665 millions USD.
[17] An additional 5 per cent tariff, for example, on very large sectors would probably provides better results, by simply collecting additional tariff revenues.
[18] Like in the "Hormones" case where USA and Canada target European agriculture exports with 100% tariffs applied to a selected panel of products.

The simple selection process relies on the "nullification and impairment" WTO concept[19]. We choose a practical way of determining products at the HS6 level that will be subject to a tariffs increase[20]. The MAcMap-HS6 database provides an advalorem equivalent of 5,113 products for almost 170 importing countries against 220 exporting countries. We match tariff data with the most recent year of available trade between the EU and the complainants.[21] Focusing on agricultural products,[22] we exclude European ones that benefit from free access to each complainant's markets and those that already face tariff duty equal (or higher) to 100%. We sort by descending order the value of complainants' imports coming from the EU and stop when we match the total losses of complainant's export to the EU coming from MIRAGE-e's simulations. Following this methodology, retaliation can thus take place in different sectors, but also in the same sector.

EFTA is considered as a follower. Thus, it is not concerned by retaliation. We assume that only retaliation against EU may have an impact on this policy and might be able to affect European choices.

Methodology

TR scenario incorporates trade retaliation in response to the introduction of European BCA. Specifically, those are applied as early as 2014. Indeed, complainants calculate their loss of export on the European market during the year 2013. Rise in tariffs applied to European Union thus increase the following year. Table 3 shows the evolution of customs duties applied by China, India and the USA to European and French exports.[23] A constant level of retaliation is applied from 2014 to 2025.

Table 3 - Variation of tariffs in sector subject to retaliation (percentage, 2014 to 2025)

Sector	Exporter	Importer	BCA	TR
Crops	France	India	76,77	98,98
Crops	Rest of EU27	India	50,00	97,78
Industry	France	China	6,43	6,47
Industry	France	India	18,47	23,60
Industry	France	USA	3,54	3,94
Industry	Rest of EU27	China	5,99	5,99
Industry	Rest of EU27	India	18,36	22,11
Industry	Rest of EU27	USA	3,17	3,30
Livestock	France	India	13,68	46,09
Livestock	Rest of EU27	India	13,62	51,42
crp	France	China	5,30	5,30
crp	France	India	17,65	18,41
crp	Rest of EU27	China	5,12	5,12
crp	Rest of EU27	India	15,75	16,34

Source: own calculations based on MAcMapHS6

Retaliation takes place in a few sectors, due to the limited impact of BCA on trade flows in ETS sectors. China and USA raise their tariffs on a few HS6 lines whereas India, whose trade flows with EU are smaller, will increase tariffs on 650 HS6 products, belonging to various MIRAGE-e aggregated sectors. Some of those are significantly impacted in terms of applied protection.

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[19] Damage to a country's benefits and expectations from its WTO membership through another country's change in its trade regime or failure to carry out its WTO obligations.
http://www.wto.org/english/thewto_e/glossary_e/nullification_and_impairment_e.htm

[20] Determining endogenously tariffs to match a given amount of exports with Mirage-e can also be considered. However, using such methodology does not necessarily provide a more realistic list of products.

[21] We use CEPII's dataset, named BACI, for year 2009. It is an harmonized version of COMTRADE data at the HS6 level.

[22] The trade volumes of the first HS6 lines of Industrial products at this level are, in terms of European exports to complainants'markets, higher than the losses of trade undergone by complainants on ETS products.

[23] At the HS6 level, customs duties are identical. Agregation procedure at the MIRAGE level gives different sector average.

3.4. Indicators of carbon leakage

In line with the literature we consider the leakage rate both at regions and sectors level. We define the leakage rate for a group of countries implementing emissions-related policies at the same time. For instance, we will consider for ETS scenario a leakage rate between countries with pledges and other countries, in contrast with the reference scenario. Regarding BCA and TR scenarios, we will focus on the leakage rate relative to ETS scenario, only for EU and EFTA which are the only country groups which change their environmental policy. The total leakage rate is defined by:

$$LR = -\frac{\Delta\,(CO2_{OUT})}{\Delta\,(CO2_{IN})}$$

Two main channels of carbon leakage have been identified in the literature (Reinaud, 2008a). A first one, sometimes called "energy-price-driven leakage", goes through the energy markets. That is, climate policies decrease the international prices of oil, gas and coal; hence it increases their use in countries without a climate policy. Another channel, often called "the GHG-intensive industry" channel, or "competitiveness-driven" route, is related to competitiveness. For instance, the EU ETS increases the production cost of European producers in GHG intensive sectors, some of which are exposed to international competition. If European producers pass through the cost to consumers, then they may lose some market shares vis-à-vis foreign producers. If they do not pass through the cost due to international competition, then the European plants with the highest production cost may become unprofitable and cease operation. In both cases, European industry will lose some market shares in both European and foreign markets, with two main consequences: job losses and an increase in GHG emissions in non-European countries, i.e. carbon leakage.

In order to encompass the relative magnitude of these two different channels, we follow Kuik and Hofkes (2010) by decomposing leakage into two components for each sector. We consider here direct and indirect (i.e. due to electricity consumption) [24] emissions. The first component is called "substitution leakage" and quantifies the change in CO_2 emissions due to variations of the CO_2 intensity of goods. The second component, called "volume leakage", measures the change in CO_2 emissions due to variations of production volume, at a given CO_2 intensity. Namely,

$$SL_j = \Delta\left(\frac{CO2_{j,OUT}}{Y_{j,OUT}}\right) Y_{j,OUT} + \frac{CO2_{j,OUT}}{Y_{j,OUT}}\,\Delta\left(Y_{j,OUT}\right)$$

4. Results

Emissions

After Copenhagen's Agreement, a number of analyses have attempted to assess whether following the commitments will make it possible to limit the increase in average global temperature to +2°C compared to the pre-industrial era. [25] The joint conclusion is that even the most optimistic interpretations will not make it possible to achieve the long-term objective. For example, the analysis carried out by the Delink et al. (2010) concluded that the declared reductions pledges could lead to a

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[24] Emissions of electricity sectors are allocated to electricity intermediate consumers, using the share of these sectors' consumption in the production of electricity.

[25] For example, see T. Houser (2010), "Copenhagen, the Accord, and the Way Forward", Policy Brief, Peterson Institute for International Economics, PB10-5, Mars 2010. J. Rogelj *et al. (*2010), "Copenhagen Accord Pledges Are Paltry", *Nature*, 464, 1126-1128. N. Stern & C. Taylor (2010), "What do the Appendices to the Copenhagen Accord tell us about global greenhouse gas emissions and the prospects for avoiding a rise in global average temperature of more than 2°C?", Grantham Research Institute, LSE. UNFCCC (2010), "Compilation of pledges for emission reductions and related assumptions provided by Parties to date and the associated emission reductions", Note by the Secretariat, FCCC/KP/AWG/2010/INF.1.

decrease between 10.5% and 14.5% below BAU levels in 2020, considering either the low or the high pledges. Stern and Taylor (2010) find emission reductions in 2020 of similar extent, between 12% and 14% under BAU level.

While our simulations are based on the low pledges, they lead to bigger emissions reductions: as is shown in Table 4, all the three scenarios exhibit world emissions reduction around 18% below our BAU scenario in 2020.[26] This partly comes from higher world emissions in the BAU scenario generated by MIRAGE-e. For instance, out growth projections for China (and therefore our emissions projections) are much higher than other studies, due to our growth model (very high TFP growth due to large improvements in education). We will see in the following that this specificity imposes high carbon tax to respect the pledges considered.

This 18% reduction can be decomposed between an emissions reduction of 9.5% in 2020 below BAU in the developed countries and an increase of 33.3% in the developing countries.

An interesting result is the higher decrease of the world emissions in the BCA scenario than in the ETS scenario: a 0.1 point in percentage represents around a difference of 40 $MtCO_2$, i.e. 13% of the French emissions in 2020 (BCA scenario). The emissions reductions between BCA and ETS scenarios are in both the countries with pledges and the countries without. On the other hand, the world emissions reduction is the same in the BCA and the TR scenarios.

Note that these emissions variations are total variations (i.e. including private and government consumption). The percentage changes may then not match the pledges cited above.

[26] In the model, India's pledge has not been taken into account because its emissions remain below the emissions allowed under the pledge.

Table 4 – Emission reduction in 2020 (percentage deviation from baseline)

	ETS	BCA	TR
Countries with pledges in the model	-24.24	-24.34	-24.34
France	-9.00	-9.28	-9.22
Other EU27	-20.77	-21.50	-21.51
EFTA	-8.76	-9.04	-8.97
USA	-17.37	-17.36	-17.35
Canada	-17.42	-17.41	-17.40
Japan	-26.66	-26.65	-26.65
Oceania	-32.31	-32.31	-32.30
Rest of Europe	-0.95	-1.09	-1.08
Brazil	-28.61	-28.59	-28.58
Russia	-15.27	-15.28	-15.28
China	-35.92	-35.92	-35.92
South Africa	-19.89	-19.88	-19.88
Countries without pledges in the model	+4.46	+4.35	+4.36
India	-0.13	-0.23	-0.24
Oil producers	+2.64	+2.71	+2.70
Other Latin America	+3.88	+3.71	+3.69
Other South-East Asia	+5.17	+5.07	+5.07
LDC	+7.24	+6.70	+6.71
Other	+5.35	+5.27	+5.30
World	-17.99	-18.09	-18.09

Source: own calculations

As the ETS scenario integrates the pledges of the rest of the world, we present leakage rates regarding the acting coalition in the ETS scenario. For the BCA scenario, leakage rate would not make sense due to the change in EU constraint (by the enlargement of the emissions reduction perimeter to importers). In addition, emissions increase in the EU under the BCA scenario, compared to the ETS one, and the signs of leakage rate would be confusing. Table 5 presents emission leakage variations under the first scenario (leading to a 4.5% leakage rate). We also add, as a comparison with other studies (such as Manders and Veenendaal, 2008), results with the EU taking alone emission reduction commitments. We assume that Members states, jointly with EFTA, implement the 20% reduction target to 2020, whereas other countries do not reduce its emissions. This way, leakage rate from European Union amounts to 14.0%.

Table 5 – Emission leakage due to ETS ($MtCO_2$) in 2020

	EU alone	ETS scenario
Coalition emissions	-	17662
EU emissions	2490	2490
Non-coalition emissions	30807	9215
Leakage rate	14.0	4.5

Source: own calculations

Macroeconomic implications

Quantitative analyses provide a large panel of indicators, helping to determine if whether a policy is preferable or not. Magnitude or omitted assumptions (mainly due to lack of data or to numerical difficulties) can always be discussed. However, they give a first snapshot of economic consequences resulting of political decisions. The simulated world welfare changes associated with GDP and exports variations are reported below in Table 7.

Table 7 - Long run changes in macroeconomics indicators, World (percent deviation from baseline, 2020)

Variable	ETS	BCA	TR
World Welfare	-0,40	-0,41	-0,42
World GDP (volume)	-0,37	-0,38	-0,39
Exports (volume)	-1,28	-1,36	-1,90

Source: own calculations

Climate policies have a significant economic cost. It is even more the case, in a framework like ours, when technical progress or positive externalities (impact of reductions in C02 emissions on welfare, for example) are not taken into account. That being said, our objective is more to assess the consequences of the introduction of the BCA by the European Union and trade retaliation it can faced if its partners bring the case to WTO. The ETS scenario is in line with similar scenarios, simulated with other CGE models on this topic. The results therefore show significant declines for conventional macroeconomic indicators for most countries of the world. Thus, the world welfare (-0.4%), world GDP (-0.37 %) and world exports (-1.28%) are negatively impacted by the commitments undertaken to reduce emissions of greenhouse gases. It is thus a world in recession – voluntary[28] – that exhibits Mirage in 2020. The introduction of the European BCA (scenario BCA) adds an additional constraint on production and trade. The macroeconomic picture marginally varies, but one can see that, in terms of trade, such a policy increases Durban's pledges economical cost. Comparatively to scenario ETS, world welfare and world GDP decreases by 0.01 percentage point. World exports follow this fall (almost by 0.1 point). Trade retaliation does not concern a large share of bilateral trade. Overall consequences get close to zero and welfare and GDP stay close to the losses provided by the BCA scenario (0.01 pp). Trade is logically more impacted, by a decline of around 0.5 pp.

Country-specific implications

In the EU and EFTA countries, the CO_2 price differs between ETS and non-ETS sectors. Table 8 presents the evolution of the price of the allowances in the ETS sectors. The price increases quickly during the period up to around 60 USD but the CO_2 price remains higher in the non-ETS sectors during the whole period. The price in the BCA scenario is always marginally higher than in the ETS scenario. This may come from an increase in allowances demand, due to production repatriation.

[28]The representative agent, in a recursive dynamic set up, is myopic: he has not any rational expectations and cannot modify his behavior

Table 8 – Evolution of the allowance price (in 2004 USD)

	2010				2020			
	EU	**ETS**	**BTA**	**TR**	**EU**	**ETS**	**BTA**	**TR**
EU27 and EFTA								
ETS sectors	1.9	4.0	4.0	4.0	53.0	60.0	66.9	66.6
Non-ETS sectors	6.0	7.7	7.7	7.0	59.8	68.0	69.3	67.7
USA	-	12.5	12.5	12.5	-	35.2	35.2	35.2
Oceania	-	19.9	19.9	19.9	-	62.1	62.2	62.2
Russian Federation	-	13.4	13.4	13.4	-	20.7	20.2	20.2
Rest of Europe	-	0.0	0.0	0.0	-	5.0	2.9	2.8
Canada	-	11.9	11.9	11.8	-	42.3	42.3	42.3
Japan	-	14.2	14.2	14.2	-	143.2	143.5	143.5
China	-	20.7	20.7	20.8	-	58.8	58.8	58.8
Brazil	-	22.5	22.5	22.4	-	130.6	131.3	131.3
South Africa	-	3.0	3.0	3.0	-	10.8	10.3	10.3

Source: own calculations

This table also allows encompassing the weight of pledges constraints in the other countries. For instance, Brazil and Japan face the highest constraints, reaching more than 100 USD in 2025. On the contrary, commitments by the Russian Federation as well as South Africa are easier to sustain (respectively 20 and 11 USD per ton of CO_2), and even more India which pledge is not constraining emissions in our simulation. Constraints on the rest of Europe are null in the beginning of the period, and remain low in 2020, but that may be due to our aggregation which links carbon markets in acting countries (Belarus, Croatia, Moldova) with non-acting one (Ukraine and Albania). This ranking of constraints by country is coherent with the literature (see for instance Delink et al, 2010), as well as the order of magnitude of carbon prices.

Although macroeconomic indicators shows that world results are clearly negative, the integration of Durban's commitments and EU ETS provides a contrasted picture of the world in 2020 at the country level (Table 9).

Table 9 - Long run change in macroeconomics indicators, by country (percent deviation from baseline, 2020)

Region	Welfare			GDP (volume)			Terms of trade			Exports (vol - no intra)		
	ETS	BCA	TR	ETS	BCA	TR	ETS	BCA	TR	ETS	BCA	TR
France	**0,08**	**0,09**	**0,22**	**-0,06**	**-0,07**	**-0,03**	**0,49**	**0,54**	**0,96**	**-0,70**	**-0,78**	**-2,20**
Rest of EU27	**-0,12**	**-0,14**	**-0,26**	**-0,19**	**-0,22**	**-0,29**	**0,23**	**0,28**	**0,12**	**-1,21**	**-1,62**	**-1,13**
EFTA	**-0,49**	**-0,49**	**-0,46**	**-0,15**	**-0,15**	**-0,14**	**-1,20**	**-1,19**	**-1,11**	**0,49**	**0,42**	**0,65**
Australia New Zealand	-1,14	-1,14	-1,12	-0,57	-0,57	-0,57	-2,47	-2,48	-2,42	-1,73	-1,73	-1,60
Brazil	-0,80	-0,79	-0,76	-0,62	-0,61	-0,60	-0,32	-0,26	-0,14	-2,66	-2,47	-2,06
Canada	-0,35	-0,35	-0,34	-0,29	-0,29	-0,28	-0,22	-0,22	-0,20	-0,91	-0,89	-0,83
China	-1,98	-1,97	-1,93	-1,91	-1,90	-1,88	1,10	1,11	1,16	-3,84	-3,84	-3,66
India	0,66	0,64	0,67	0,39	0,37	0,38	1,09	1,05	1,19	0,87	0,71	0,29
Japan	-0,32	-0,31	-0,31	-0,44	-0,44	-0,44	1,43	1,46	1,49	-4,18	-4,14	-3,98
Latin America	-0,25	-0,26	-0,24	-0,04	-0,05	-0,04	-1,07	-1,09	-1,04	-0,52	-0,58	-0,41
LDC	-0,76	-0,79	-0,74	-0,24	-0,25	-0,22	-1,69	-1,74	-1,70	0,19	0,02	0,21
Oil Producing countries	-1,97	-1,98	-1,97	-0,54	-0,53	-0,53	-3,28	-3,31	-3,28	-0,55	-0,55	-0,49
Other Europe	0,82	0,33	0,36	0,14	0,05	0,06	1,02	0,34	0,38	0,25	-0,84	-0,67
Other South East Asia	0,06	0,05	0,12	-0,04	-0,04	-0,01	0,04	0,03	0,07	-0,08	-0,10	0,08
Rest of the World	0,22	0,22	0,27	0,07	0,08	0,10	0,16	0,16	0,22	-0,17	-0,17	0,04
Russian Federation	-1,63	-1,71	-1,68	-0,88	-0,91	-0,90	-1,53	-1,65	-1,61	-2,76	-2,91	-2,84
South Africa	-0,31	-0,32	-0,29	-0,23	-0,22	-0,21	-0,55	-0,60	-0,55	-0,78	-0,75	-0,56
USA	-0,18	-0,19	-0,18	-0,20	-0,20	-0,20	0,21	0,21	0,25	-1,61	-1,64	-1,54

Source : own calculations

Adopting a carbon policy is not costless, especially for countries targeting an ambitious reduction in carbon emissions. Such commitments necessarily require important economic adjustments. In ETS scenario, impacts on welfare impacts are negative for a large majority of countries, China (closed to a decline of 2%) and Russia (-1.6%). On the other hand, Oil Producing Countries also face a high decrease in their welfare (around 2%) due to a negative terms of trade effect and to large drops in their revenues coming from fossil fuels sectors. Commitments, through the creation of a new tax on consumption, cause mechanical losses in allocation efficiency and thus a reduction of welfare. EU26's welfare decreases by 0.1%. On the contrary, France, whose commitments are relatively lower than other European countries (see table 4), performed better: French welfare increases by 0.1%. India is the main winner in this scenario (+0.7%), thanks to its level of emissions which is below the pledge. India is joined by other european countries (+0.8%) but their level of consumption remains lower. BCA scenario does not significantly change the welfare analysis. It rises marginally looses for most countries. EU's policy has visible consequences for other Europe and marginal ones for most of the countries (for example, India, Oil producing countries or South Africa suffer a lost 0.1 point between BCA and ETS scenario). Some countries (e.g. Brazil and Japan) benefit from the tax imposed by the EU, thanks to terms of trade gains. Their large commitments also explain a potential advantage to export to the EU compared to other countries whose commitments are lower (and thus, the European BCA act as new important constraint for them). In the TR scenario, our results are in line with Anderson's (2002) theoretical statement (trade loss equivalent never translates into equivalent damage to economic welfare) and with some applied modeling results (Breuss, 2007). In general, both the complainant and the respondent suffer a welfare loss in the case of retaliation. Welfare variations by country confirm this: France and EU26 undergo a decline in utility (when comparing TR scenario to BCA scenario). However, rises in tariffs do not only affect exporters (here, the EU) but also hurts complainants' consumers and, hence, possibly their welfare (imported goods from EU become more expensive; close substitute from other countries might be more expensive as well). Given the small amount in play, it is unsurprising that those negative effects remain marginal at the national level. Other countries' welfare is also affected by additional tariffs applied to EU by complainants. China, India and the USA are large countries. Thus, contrary to small open economies for which optimal tariff is zero, implementing retaliation measures through additional tariff may improve their terms of trade. The positive variations of the latter for those three countries confirm that they can have an interest in raising their tariffs against the EU27. The effect is more important for India, even if the magnitude of these variations is low.

From a mercantilist's point of view, trade remains an important indicator, illustrating changes in specialization. In ETS scenario, a few countries experience an increase in their exports: India (+0.9%) and EFTA (+0.5 %), who especially well performed in exports in ETS sectors to the rest of world. Indeed, their emission reductions are relatively lower than the ones undertaken by EU27, creating competitive advantages for this group of countries. Other countries all export less than in the reference scenario, some of them significantly: China (-3.8%) and Japan (-4.2%). Australia/New Zealand, Brazil, European Union and USA constitute another bulk of countries that looses between 1 and 3% of exports to the rest of world. Concerning extra-trade, BCA scenario is not such a good option for European trade: all European countries experiment a decline in their exports in 2020 compared to the ETS scenario. The introduction of the BCA however benefits to some trade partners, especially the ones whose commitments are important (Japan and Brazil for example). If overall trade is reduced in the TR scenario, retaliation of China, India and the USA allow some trade diversion effect switching imports from Europe to other partners, except India.

Focus on European Union

European Union is the point of interest. The following section examines the consequences of our set of scenarios on this region, associated to EFTA. As global macroeconomic variations have already been studies in previous sections, focus is given to trade, regarding whether EU is importer or exporter. Table 10 presents the variations of European imports. Table 11 shows what happens on the exports side.

Table 10 - Variation in bilateral european imports (percent deviation from baseline, 2020)

Exporter \ Importer	Rest of EU27			France			EFTA		
	ETS	BCA	TR	ETS	BCA	TR	ETS	BCA	TR
Australia New Zealand	1,02	1,59	2,15	0,98	1,46	3,09	2,56	3,46	3,04
Brazil	-0,74	1,37	4,29	0,65	2,12	5,26	-6,28	-1,55	-2,25
Canada	-1,89	-1,62	-1,30	-0,69	-0,37	1,25	-2,29	-1,57	-1,95
China	-1,82	-1,66	-0,92	-0,76	-0,57	2,40	-1,45	-1,27	-1,75
EFTA	0,38	0,67	0,62	-0,72	-0,71	0,62	0,15	0,17	0,04
France	0,60	0,90	0,19	0,00	0,00	0,00	-0,15	0,21	-1,73
India	0,94	-0,75	-0,97	1,34	0,24	2,32	0,89	-0,49	-1,36
Japan	-1,61	-0,63	0,15	-1,59	-0,46	2,75	-3,00	-1,88	-2,37
Latin America	-0,07	-0,82	0,53	1,80	1,51	3,50	3,53	2,83	2,28
LDC	3,53	1,41	2,44	3,48	1,86	4,95	5,52	3,44	2,98
Oil Producing countries	-2,46	-1,97	-2,09	-4,15	-3,90	-3,29	7,46	7,33	7,12
Other Europe	0,97	-8,83	-8,82	-1,36	-6,50	-5,56	-0,15	-9,50	-9,60
Other South East Asia	1,00	0,87	1,29	1,70	1,49	3,70	1,15	1,22	0,82
Rest of EU27	0,01	0,13	-4,78	0,32	0,38	-2,96	-0,37	-0,25	0,54
Rest of the World	0,32	0,36	1,19	0,26	0,61	3,70	0,09	0,05	-0,35
Russian Federation	-2,81	-4,08	-4,30	-3,65	-4,62	-4,50	-2,32	-3,96	-3,98
South Africa	-6,16	-6,10	-5,55	-1,11	-0,35	2,12	1,38	1,58	1,12
United States of America	-1,78	-1,92	-1,68	-0,75	-0,84	1,40	-0,90	-1,02	-1,49

Source: own calculations

Under ETS scenario, exports from the rest of world to the EU shrink. Environmental policies undertaken by partners reduce their possibility to trade with the EU, promoting tierce partners who did not commit (LDC, India, Latin America and Oil producing countries). Among countries that took commitments, Australia/New Zealand and EFTA manage to export more to the European Union.

In BCA scenario, some countries become highly constrained when exporting to EU: India, other Europe, Russia or LDCs (whose exports still positively vary but decline sharply compared to ETS scenario). In TR scenario, imports logically decrease of imports. European production is however favored: trade inside EU26 is rising compared to BCA scenario as well as trade as well as trade between France and EU26. So EU faces a negative terms of trade effect and thus its goods become less competitive when exporting.

Table 11 - Variation in bilateral european exports (percent deviation from baseline, 2020)

Importer \ Exporter	Rest of EU27			France			EFTA		
	ETS	BCA	TR	ETS	BCA	TR	ETS	BCA	TR
Australia New Zealand	-3,09	-3,40	-2,19	-3,20	-3,55	-5,00	-1,04	-1,42	-1,12
Brazil	0,37	0,09	1,47	2,13	1,84	0,82	4,93	4,57	5,05
Canada	-0,54	-0,88	0,38	0,37	-0,04	-1,14	-4,47	-4,58	-4,38
China	-0,59	-1,04	0,30	2,18	1,71	0,46	-6,20	-6,43	-6,07
EFTA	-0,37	-0,25	0,54	-0,15	0,21	-1,73	0,15	0,17	0,04
France	0,32	0,38	-2,96	0,00	0,00	0,00	-0,72	-0,71	0,62
India	0,60	0,16	-2,74	-0,46	-1,11	-14,83	1,88	1,02	1,65
Japan	1,48	1,21	2,58	2,40	2,09	1,02	4,67	4,26	4,70
Latin America	-1,27	-1,67	-0,39	-1,68	-2,12	-3,17	0,12	-0,28	0,05
LDC	-1,67	-2,18	-0,87	-1,79	-2,38	-3,67	-0,14	-0,82	-0,40
Oil Producing countries	-4,37	-4,70	-3,72	-4,65	-5,02	-6,55	-2,79	-3,29	-3,09
Other Europe	0,63	-1,60	-0,83	1,03	-1,21	-3,00	3,64	0,90	0,81
Other South East Asia	0,28	-0,03	1,23	-0,17	-0,55	-1,61	1,49	1,10	1,48
Rest of EU27	0,01	0,13	-4,78	0,60	0,90	0,19	0,38	0,67	0,62
Rest of the World	0,52	0,11	1,50	0,28	-0,13	-1,38	2,44	1,94	2,34
Russian Federation	-3,35	-4,38	-3,58	-3,15	-4,27	-5,97	-3,11	-4,07	-4,14
South Africa	-1,47	-1,79	-0,65	-1,54	-1,88	-3,47	0,91	0,54	0,81
United States of America	-0,07	-0,42	0,48	-0,14	-0,54	-2,85	-0,62	-0,87	-0,59

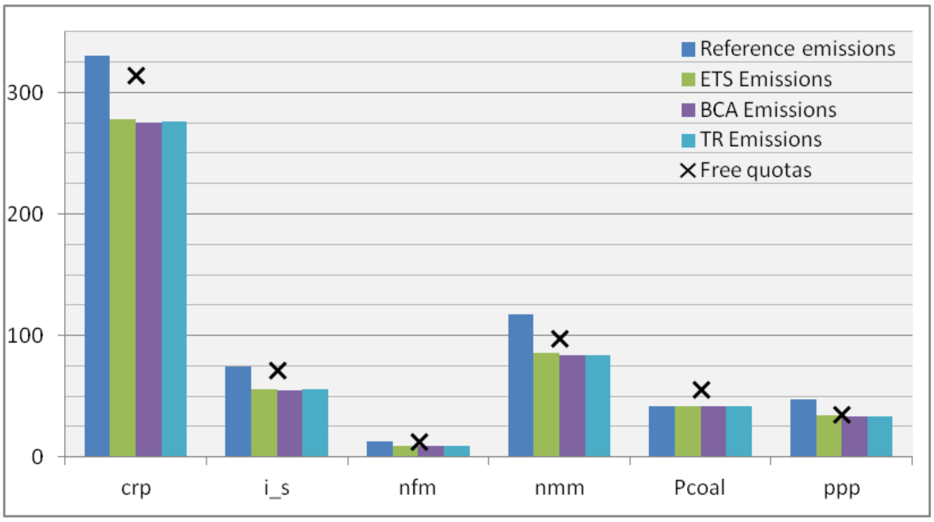
Source: own calculations

Commitments taken in Durban (ETS scenario) reshape world trade: EU increases its trade with some its partners: Brazil, India, Japan, Other South East Asia, the rest of the word and with itself (both for France et other member states). Globally, the magnitude of losses and gains on world market for EU countries does not significantly vary between ETS and BCA scenario.

As EU and France are separated, some interesting results come up in the TR scenario: EU26 is positively impacted by trade retaliation applied by China and the USA, at the expense of France which face a higher average tariff (due to its trade structure with these countries). Indian retaliation clearly negatively impacts France and the rest of EU27. However, the level of trade is less important than with the two other countries. In the same time, EU increases its exports (or reduces its losses) to the rest of the world, whereas France losses on every markets, due a rise in French export prices.

The decomposition of EU emissions between ETS sectors (excepted Electricity) is given by figure 2, as well as the free allocation level for these sectors. The first conclusion is that the BCA does not really affect EU emissions in these sectors. The other observation is that excepted nfm and ppp, the level of free allocated quotas for year 2020 is well above the projected level of emissions.

Figure 2 – Sector-specific emissions and allocations, selected sectors in EU (2020, $MtCO_2$)



Source: own calculations

When a BCA is implemented in the EU ETS (BCA scenario), the emissions of the rest of the world slightly decrease in several countries, in particular in the regions without pledge. Two mechanisms explain this result. Firstly, the emissions covered by the ETS are more important with a BCA than without, since the cap is put on the emissions of the importations as well. Secondly, the slightly higher allowance price in the BCA scenario traduces a slightly stronger constraint in the EU ETS.

Table 12 – Sectoral emission leakage and correction in 2020 ($MtCO_2$)

	EU alone scenario (deviation from BAU)				BCA scenario (deviation from ETS)			
	EU	Non-EU			EU	Non-EU		
			of which				*of which*	
			Subsitution	***Volume***			***Subsitution***	***Volume***
Direct emissions variation	-816.71	114.12	-	-	-29.94	-10.33	-	-
Total emissions variations	-479.36	106.86	*79.74*	*27.12*	-21.87	-8.36	*1.16*	*-9.46*
ETS sectors								
Chemical, rubber and plastic	-58.25	25.33	*18.85*	*6.48*	-2.47	-7.97	*4.36*	*-12.24*
Paper products and publishing	-34.07	3.53	*2.91*	*0.62*	-1.61	-0.10	*-0.16*	*0.06*
Ferrous metals	-29.81	11.88	*6.71*	*5.17*	-1.17	-1.10	*0.23*	*-1.34*
Other metals	-21.70	10.06	*4.54*	*5.52*	-1.04	1.04	*-0.05*	*1.09*
Other mineral products	-18.79	4.41	*3.28*	*1.12*	-0.84	-0.81	*0.28*	*-1.09*
Petroleum and coal products	-5.01	2.31	*1.02*	*1.29*	-0.22	0.66	*0.38*	*0.28*
Subtotal	-167.63	57.52	*37.32*	*20.20*	-7.35	-8.29	*5.03*	*-13.24*
Non-ETS sectors								
Services	-180.83	19.95	*22.62*	*-2.67*	-8.28	-2.89	*-2.91*	*0.02*
Other Industry	-70.39	11.41	*10.39*	*1.01*	-3.52	1.83	*-0.66*	*2.48*
Transport	-24.34	22.57	*6.04*	*16.54*	-1.10	0.90	*0.12*	*0.77*
Metal products	-8.95	1.22	*1.21*	*0.02*	-0.45	0.41	*0.00*	*0.41*
Crops	-6.76	1.83	*1.29*	*0.54*	-0.34	0.01	*-0.20*	*0.21*
Other extraction	-5.70	1.88	*1.73*	*0.15*	-0.28	-0.06	*-0.13*	*0.07*
Livestock	-4.98	1.14	*1.03*	*0.11*	-0.24	0.00	*-0.12*	*0.12*
Coal	-6.54	-2.41	*-0.52*	*-1.89*	-0.21	-0.10	*-0.04*	*-0.06*
Gas	-2.43	-8.01	*-1.45*	*-6.57*	-0.08	-0.20	*0.02*	*-0.22*
Oil	-0.81	-0.25	*0.07*	*-0.32*	-0.02	0.03	*0.05*	*-0.02*
Subtotal	-311.72	49.34	*42.42*	*6.92*	-14.52	-0.07	*-3.87*	*3.78*

Source: own calculations

When EU takes commitments alone, sectoral leakage is heterogeneous, ranging from 10 to 46% in ETS sectors, and from 11 to 32% in non-ETS sectors (excl. Transport), with respective average leakage of 33 and 16% (see Table 12). These leakage rates are mainly variations in carbon intensity ("substitution" or "energy" channel). Indeed, world price of coal lowers by 2.2% in this scenario and gas price is lowered by 1.1%, as shown in Table 13.

Table 13 – Variation in world price of energy goods (percentage deviation from BAU)

	EU alone	ETS	BCA	TR
Coal	-2.2	-17.8	-18.0	-18.0
Oil	-0.2	-3.6	-3.6	-3.6
Gas	-1.1	-2.8	-2.9	-3.0
Petroleum and coal products	-0.2	-3.2	-3.2	-3.2
Electricity	6.6	10.7	11.6	11.5

Note: These average prices are geometric averages, weighted by trade flows.
Source: own calculations

As noted before, leakage out of EU cannot be addressed properly in the ETS scenario, due to the fact that a lot of countries act at the same time. We could however have the intuition that the same mechanisms may occur. World average prices lower in the ETS scenario a lot, especially coal (-17.8%) and may lead to "substitution" leakage outside EU.

Eventually, we observe leakage correction due to the implementation of BCA. In the BCA scenario, two effects compete. Firstly, emissions outside EU are driven down by a decreasing demand in EU for imported goods in ETS sectors (negative "Volume" leakage, mainly in the Chemical, Rubber and Plastic sector). Secondly, though to a lower extent, world prices of energies lower and imply some "substitution" leakage in the same sectors. This way, BCA could indeed be considered as a trade measure, given that it decreases EU imports. Finally, the decrease in EU ETS sectors is mainly explained by the enlargement of the ETS perimeter, leading to higher constraints.

Regarding non-ETS sectors, there is no protection effect of BCA, such that deviation differs across sectors and equilibrates on average. The substitution effect is mainly negative and may result from a different allocation between countries outside EU because a lot of these countries are constrained by their Copenhagen commitment.

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Appendix: Free CO_2 quota allocation

For exposition purpose, we simplify the framework and consider that a representative firm has the following profit function, given that it produces Y_j, sold at price PY_j and employs labor L_j and capital K_j at prices w_j and r_j. The firm also faces a carbon τ^{CO2} based on its CO_2 emissions $EmCO2_j$, but a certain amount $\widetilde{CO2}_j$ is exempted from taxes.

$$\Pi_{j,r,t} = P^{Y}_{j,r,t} Y_{j,r,t} - w_{j,r,t} L_{j,r,t} - r_{j,r,t} K_{j,r,t} - \tau^{CO_2}_{r,t} \left(EmCO2_{j,r,t} - \widetilde{CO2}_j \right)$$

This profit function can be reorganized the following way, after Fisher and Fox (2007):

$$\Pi_{j,r,t} = \left(1 - \tilde{\tau}^{CO2}_{r,t}\right) P^{Y}_{j,r,t} Y_{j,r,t} - w_{j,r,t} L_{j,r,t} - r_{j,r,t} K_{j,r,t} - \tau^{CO_2}_{r,t} EmCO2_{j,r,t}$$

With $\tilde{\tau}^{CO2}_{r,t}$ representing an endogenous production subsidy which matches the amount of freely allocated CO_2 quotas.

$$\tilde{\tau}^{CO2}_{r,t} = -\frac{\tau^{CO_2}_{r,t} \widetilde{CO2}_j}{P^{Y}_{j,r,t} Y_{j,r,t}}$$