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# Border Carbon Ajustment in Europe and Trade Retaliation: What would be the Cost for European Union?

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## Highlights

- A border carbon adjustment in the European Union would imply export losses in the first year of implementation, which would mainly affect the USA (2 billion dollars), Russia (1.8 billion), and China (1 billion).
- Although small at the macroeconomic scale, these export losses would certainly lead to disputes at the World Trade Organization (WTO).
- The possible ensuing trade retaliation would entail export losses for the EU focused on agricultural goods, of an order of magnitude of 6 billion dollars, as soon as retaliation begins.
- Energy intensive and trade exposed sectors in the EU would increase production due to the BCA, compensating for around 20% of the drop due to carbon pricing, at the expense of production by partners. This effect would be magnified in the case of trade retaliation.
- Other European sectors would be penalized by both the BCA and trade retaliation; whereas consumers' real income would not be significantly impacted, making a BCA more dependent on the political weight of the sectors concerned.

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## Abstract

Unilateral climate policy, such as carbon pricing, represents an additional cost to the economy, especially to energy-intensive industrial sectors, as well as those exposed to international competition. A border carbon adjustment (BCA) is often presented as an attractive policy option for countries that want to go ahead without waiting for a global climate agreement. We used the computable general equilibrium model MIRAGE-e to simulate the impact of the introduction of a BCA on imports of energy intensive products in EU and EFTA countries and to evaluate the export losses their main trade partners would suffer. Given that a BCA is a trade measure, it would certainly lead to disputes at the World Trade Organization (WTO). If the BCA is considered illegal, the losses suffered by some partners may justify retaliation, as authorized by a WTO dispute settlement. The overall aggregated impacts of these measures would be negative but marginal, meaning that neither the BCA nor trade retaliation would have a marked impact on consumers' real income or GDP, while prohibitive retaliatory tariffs are more likely to target sensitive products in the EU. A BCA would ultimately be a signal of the EU's willingness to maintain an ambitious climate policy.



## Keywords

Emission trading scheme, border carbon adjustment, trade retaliation.

## JEL

D58, F18, Q56.

**Border carbon adjustment in Europe and trade retaliation: What would be the cost for European Union?** [1]

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## 1. Introduction

Effective and efficient climate protection ultimately requires cooperative action across all major greenhouse gas (GHG) emitting countries. But the agreement reached in Copenhagen in 2009 has led to a fragmented world in which each country has unilaterally decided (or not) to reduce its GHG emissions by 2020, as well as the intensity of the reduction. The current climate regime groups some countries who are trying to move forward, others who seek to reduce their emissions but without really departing from "business-as-usual" and others who have no commitment to emission reduction. In this fragmented climate regime, a border carbon adjustment (BCA) is sometimes seen as an appealing policy option for countries who intend to implement more stringent unilateral policies and worry about possible carbon leakage, which would jeopardize the effectiveness of their action (Krugman, 2009; Helm et al., 2012).[2]

The aim of a BCA is basically to level the playing field by imposing a similar constraint on the GHG emissions of the imported and domestically produced goods. Applied as a complementary instrument to binding domestic emission pricing, a BCA can reduce carbon leakage and increase global cost effectiveness. Focusing on the Kyoto protocol and assuming countervailing carbon levies for all sectors in countries who are reducing their GHG emissions, Babiker and Rutherford (2005) found that BCA can substantially reduce the real income losses for the coalition members by shifting a great part of the carbon policy burden to non-coalition members. A recent

[1]We thank Nicolas Lagarde for his participation in early developments of this paper. We also acknowledge helpful advice from Lionel Fontagné, Sébastien Jean, the French Ministry of Finance and the participants to the $15^{th}$ Annual Conference on Global Economic Analysis and to the $3^{rd}$ Association of Environmental and Resource Enconomists Summer Conference. All errors remain ours.

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[2]A unilateral climate policy in a country can increase emissions (i.e. carbon leakage) in non-abating (or less acting) countries. Indeed, the climate policy reduces the consumption of some fossil fuels in the abating country, and hence their price. This encourages the rest of the world to consume more fossil fuels as their price has gone down. Another source of carbon leakage is possible loss of market shares by domestic firms in favor of foreign firms, due to the imposed carbon constraint, or the migration of industrial sites towards regions with a less stringent climate policy. A BCA can only limit the carbon leakage of the latter type. Carbon leakage impairs the effectiveness of a climate policy.

initiative by the Energy Modelling Forum, an international expert platform for the discussion of energy and environmental problems, investigated the efficiency and distributional impacts of BCA as a complementary instrument to domestic climate policy and reached the same conclusions (Böhringer et al., 2012b).[3] Thus, while border carbon adjustments do have some appeal based on their implications for carbon leakage and global cost effectiveness, they also shift a larger part of the economic abatement from regions who implement the BCA to other regions, including developing countries. This loss of agents' real income might create an incentive for non-acting (or less acting) countries to price carbon,[4] but also to implement trade retaliation.

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, including a report from WTO-UNEP (2009), conclude that theoretically it is possible to design a WTO-compatible border adjustment (Ismer and Neuhoff, 2007; Pauwelyn, 2007; Eichenberg, 2010), the risk of a WTO dispute arising over climate related trade measures is high (Werksman et al., 2009; Holmes et al., 2011).

Some developing countries have already expressed their concerns about the use of trade measures for carbon motives and affirmed their determination to fight all initiatives of this kind. 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). Before the international conference on the climate in Doha in December 2012, with China's support, India pre-emptively asked the United Nations to table a proposal to ban climate-related protectionist measures, including border taxes (TWN, 2012). The conflict opposing the EU and a broad coalition of countries, including Russia, India, the United States, and China, on the inclusion in the European Emission Trading Scheme (EU ETS)[5] of all the airlines operating in the EU perfectly illustrates the risk of trade war (Reuters, 2011).

While the economic impacts of border measures have already been addressed, to our knowledge no study has assessed the implications of trade retaliation for a region that implements a BCA for climate reasons. A country that wishes to use this instrument needs to assess this risk. Our objective is thus to compare possible benefits of implementing a BCA for a coalition and the costs it would have to bear if its main trade partners decided to apply retaliatory trade sanctions. This question is interesting for the more general issue of the use of trade measures as complementary policies to climate policies. We focus on the EU because this region is among the most ambitious in terms of emission reduction, and we limit the implementation of the BCA

[3]For instance, Böhringer et al. (2012a) conclude: "Regarding leakage reduction and the alleviation of adverse EITE output effects, we find that border carbon adjustments are by far the most effective instrument since they directly level the playing field between regulated domestic EITE production and unregulated EITE production abroad. Border carbon adjustments can provide non-negligible global cost savings."

[4]Barrett (2011) considers that the two primary motives for using trade restrictions are limiting carbon leakage and free riding.

[5]Since 2005, an ETS caps the GHG emissions generated by heavy and energy industries. This instrument covers more than 10,000 industrial production units in the EU, about 40% of Member States' emissions.

to the energy-intensive and trade-exposed (EITE) sectors covered by the EU ETS.

The analysis was based on the use of the MIRAGE-e model, the energy-oriented version of MIRAGE, CEPII's global computable general equilibrium (CGE) model. The first scenario represents commitments concerning reductions in GHG emissions. It models an increasing constraint on GHG emissions by highly emissive industrial sectors in the EU up to 2020 based on the decision taken by the European Parliament and Council in 2009, including the integration of the aviation sector from 2012 (European Commission, 2009). The emission reductions in the non-ETS sectors and in the rest of the world are consistent with the pledges taken during the 15th Conference of Parties of the UNFCCC held in Copenhagen in 2009 and confirmed in the Durban Agreement the following year (Dellink et al., 2011). The second scenario encompasses the implementation of a BCA to imports of EITE goods covered by the EU ETS. Like EU producers, foreign producers must surrender allowances equal to the emissions linked to the production (but not to transport) of the imported products. The third scenario assumes that the EU's main trade partners bring a WTO challenge against the BCA and apply trade retaliation compatible with the WTO framework, here modeled as an increase in custom duties.

We found that even if a BCA were applied only at the level of EITE sectors, it could lead to export losses for the EU's trade partners, to an extent that is comparable with the amounts already identified by the WTO dispute settlement as a justification for retaliation. The overall impact on European exports of both border adjustment and trade retaliation would then be slightly negative in the majority of the sectors examined. These trade measures would limit the drop in production in the EITE sectors, but at the expense of the other sectors. Nevertheless, neither the BCA nor retaliation would have sizeable impacts on real income or GDP in the EU or on the retaliators, while leading to a small decrease in global emissions.

Section 2 explains the methodology used and the policy simulations. Results are discussed in Section 3. Section 4 concludes.

## 2. Methodology

### 2.1. The MIRAGE-e model

MIRAGE-e (Fontagné et al., 2013) is adapted from MIRAGE, the multi-sectoral and multi-regional CGE model (Bchir et al., 2002; Decreux and Valin, 2007), which was developed for, and has been extensively used to assess trade liberalization and agricultural policy scenarios. Based on a sequential dynamic recursive set up, MIRAGE is used to evaluate a future for the world economy, using exogenous projections for macroeconomic variables like GDP or labor force. MIRAGE-e offers improved energy modeling whose dynamics rely on a new baseline built following the MaGE model (Macroeconometrics of the Global Economy, Fouré et al., 2013). 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 comprises imperfectly substitutable production factors: capital, skilled labor, unskilled labor, land, natural resources, and energy.

All primary factor endowments (labor, land, natural resources and capital) are assumed to be fully employed and their regional variations are exogenously taken from MaGE projections. Installed capital stock is assumed to be immobile (sector specific), while investment, which represents the long term possibility of a capital market adjustment, 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 improvements in productivity resulting from the growth model MaGE. Among energy producing sectors, substitutions between energies are allowed only for the generation of electricity. Moreover, energy productivity does not improve in other energy sectors.

## 2.2. Data and aggregation of regions and sectors

For this paper, MIRAGE-e was calibrated with data from the GTAP-7 database for the year 2004 (Narayanan and Walmsley, 2008). The database contains integrated data on bilateral trade flows and input-output matrixes for 57 sectors and 113 countries and regions, covering the whole world. Two other GTAP databases that are consistent with the previous one were also used: energy consumption and $CO_2$ emissions.

Table 1 shows how GTAP sectors and regions are aggregated in this paper. The geographical aggregation used is precise enough to represent the emission reduction commitments made in Copenhagen in 2009.

Designing an aggregation that perfectly isolates the sectors concerned by the EU ETS is not an easy task. The data sources (43 goods sectors in GTAP, corresponding e.g. to around 15,000 products in the Integrated Tariff of the European Communities – TARIC – classification) make it difficult to achieve perfect correspondence. 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, publishing, for example. Being aware of this limitation, we identified seven GTAP sectors that could correspond to the EU ETS. Except for electricity, all these EU ETS sectors are considered as EITE.

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 agricultural sectors, the rest of industry, and two service sectors.

**Table 1 – Overview of regions and sectors**

| Regions | Sectors |
|---|---|
| European Union (EU27) | **EU ETS sectors** |
| European Free Trade Association (EFTA) | Paper products, publishing (ppp) |
| United States of America (USA) | Petroleum, coal products (p_c) |
| Canada | Chemical, rubber, plastic products (crp) |
| Japan | Mineral products nce (nmm) |
| Australia and New Zealand (ANZ) | Ferrous metals (i_s) |
| Russian Federation | Metals nce (nfm) |
| Rest of Europe | Electricity (ely) |
| Brazil | **Energy sectors** |
| China and Hong-Kong (ChinaHK) | Coal (coa) |
| South Africa | Oil (oil) |
| India | Gas (gas), gas distribution (gdt) |
| Oil producing countries[a] | **Other sectors** |
| Other Latin America | Crops[c] |
| Other South-east Asia | Livestock[d] |
| Least Developed Countries (LDC)[b] | Minerals nce (omn) |
| Rest of the World | Rest of Industry |
| | Transport[e] |
| | Services[f] |

*Note:* 'nce' means 'not classified elsewhere'

[a]Venezuela, Rest of Western Asia, Islamic republic of Iran, Rest of North Africa, Nigeria

[b]Cambodia, Lao People's Democratic Republic, Indonesia,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 nce (gro), Vegetables, fruit, nuts (v_f), Oil seeds (osd), Sugar cane, sugar beet (c_b), Plant-based fibers (pfb), Crops nce (ocr).

[d]Cattle, sheep, goats, horses (ctl), Animal products nce (oap), Raw milk (rmk), Wool, silk-worm cocoons (wol), Forestry (frs), Fishing (fsh).

[e]Transport nce (otp), Sea transport (wtp), Air transport (atp).

[f]Water (wtr), Construction (cns), Trade (trd), Communication (cmn), Financial services nce (ofi), Insurance (isr), Business services nce (obs), Recreation and other services (ros), Public Administration, Defence, Health, Education (osg), Dwellings (dwe).

## 2.3. The scenarios

All counterfactual analyses depart from a scenario with no climate policy called a "Business-As-Usual" (BAU) scenario. The aim of this reference scenario is to build a framework for comparison with the simulations of climate policies. The scenario called "ETS" is a stylized version of the emission reduction commitments taken in Copenhagen in 2009 as well as the decisions taken by the EU. The "BCA" scenario differs from the ETS scenario by assuming the implementation of a BCA to imports of goods whose production in the EU is covered by the EU ETS. The "TR" scenario is similar to the BCA scenario but assumes that some trade partners of the EU who are negatively impacted by the BCA will implement trade retaliation.

In the BAU scenario, GDPs are set exogenously from the baseline growth trajectory produced with the MaGE model. Thus, total factor productivity adjusts such that GDP growth rates in MIRAGE-e match the baseline growth trajectory, under the additional assumptions on sector-specific differentials detailed in Fontagné et al. (2013).[6]

In this reference scenario, prices of fossil energies (coal, oil and gas) come from IEA (2011) projections. Local natural resources endogenously adjust to match these fossil fuel price targets, with a linear smoothing between 2005 and 2014 to overcome price volatility, which would prevent the model from solving.

Contrary to the BAU scenario, GDPs become endogenous in the simulations with climate policies, while the total factor productivities are equal to the values computed in the reference scenario. In addition, world primary energy prices become endogenous, while the corresponding reserves are assumed to remain at their reference level.

### 2.3.1. The ETS Scenario

The EU sets its GHG emission target for 2020 at 20% below 1990 levels, which represents a 14% reduction in emissions between 2005 and 2020. This is divided into a reduction of 21% in the ETS sectors and a reduction of 10% in the non-ETS sectors and households.[7]

Norway, Liechtenstein and Iceland have implemented an ETS and have linked it to the EU ETS. In MIRAGE-e, EFTA is considered as a single region. We assume that this region links its ETS to the EU ETS from 2008 and applies the same reductions in emissions as in the EU both in the ETS and non-ETS sectors.

The EU ETS gives some flexibility to firms covered by the scheme. Thus, the use of credits from Clean Development Mechanism (CDM) and Joint Implementation (JI) is allowed in the EU ETS,

[6] Namely, Crops and Livestock productivities are exogenous, while a 2 p.p. growth gap is maintained between the manufacturing and services sectors.

[7] Even if the model only covers CO2-energy emissions, we use the objectives in terms of GHG emissions.

but only up to the limits proposed in the Directive 2009/29/EC (Article 11a).[8] In MIRAGE-e, the use of international credits is modeled as a loosening of the constraint on emissions, through the availability of a greater number of allowances to the ETS sectors.[9]

After 2012, we assume that the aviation sector is included in the EU ETS.[10] However, this sector is not represented explicitly as an ETS sector in MIRAGE-e. Firstly, data on aviation do not allow identification of routes that would be subject to ETS (i.e. departing from or arriving in the EU). Secondly, while the airlines can buy allowances created for the industry and energy sectors, the reverse is not possible. According to Boon et al. (2007), airlines will be at the origin of a high demand for industrial allowances. We account for this by reducing the number of allowances available in the scheme. The number of permits that are removed comes from Boon et al. (2007), corrected by the quantity of CDM and JI credits that can be used by airlines (11%).

Since the beginning of the EU ETS, allowances have been allocated freely to industries on a lump-sum base and continue to be free for sectors exposed to the risk of carbon leakage during the third period of the scheme (2013-2020). We depart from this decision by assuming that from 2013 onwards, all the allowances are auctioned. In a CGE model with perfect competition and a single consumer-government agent, auctioned permits and free allocations are equivalent, as long as the number of permits received by firms is independent of their production.[11]

Technically speaking, the cap and trade system is implemented in the model by exogenously imposing the level of $CO_2$ emissions in the EU and EFTA (one for ETS sectors, one for non-ETS sectors plus households). As a result, two carbon prices emerge, matching the supply and demand for carbon allowances. This modeling assumption can be interpreted in two ways. First, for the ETS sectors, the corresponding price reflects the equilibrium price on the allowances market under perfect competition. Second, for non-ETS sectors and households, the price outcome corresponds to the level of carbon tax needed to achieve the reduction objective.

For other countries, we assume that the emission reduction pledges made in Copenhagen are applied.[12] Unlike under the Kyoto Protocol, the way countries report the emissions they plan to avoid is not standardized. Consequently, there is a variety of different pledges, in which designs (absolute/relative target, reference year etc.) differ considerably between countries.

[8] "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))

[9] This implies that the price of the EU allowances and of the international credits is the same.

[10] In fact, at the end of 2012, the EU decided to delay the inclusion of foreign airlines by a year to allow time to negotiate with its partners in the framework of the International Civil Aviation Organization.

[11] With auctioning, the money that is collected increases the government's revenues. On the other hand, a grand-fathered free allocation results in the redistribution of the collected revenue to the shareholders (under perfect competition), i.e. the consumer, who is the same agent as the government.

[12] For a detailed list of the pledges, see for instance Stern and Taylor (2010).

Some pledges also correspond to an interval rather than to a single figure. For instance, China will endeavor to lower its $CO_2$ emissions per unit of GDP by 40-45% by 2020 compared to the 2005 level, suggesting low and high pledges.

We only consider low pledges. Unlike EU targets, some countries have made commitments in terms of $CO_2$ intensity of GDP, or relative to the projected emissions in a BAU reference (see Table A.2). We transform their pledges into absolute targets using our BAU scenario.[13] Table A.2 lists countries' commitments, translated into our geographical aggregation.

### 2.3.2. The BCA Scenario

There are different ways of defining a BCA (Monjon and Quirion, 2010): it can target imports and exports or only imports; if imposed only on imports, a BCA can be a tax, or an obligation to surrender allowances; it can cover direct and indirect emissions, or only direct emissions, etc.

In the model, we assume that the BCA targets European imports of EITE goods, whatever their origin, from 2013 onwards. The measure obliges importers to surrender a quantity of allowances corresponding to direct CO2 emissions generated during the production of the imported goods (thus excluding emissions underlain by electricity consumption). This differs from the more common assumption that importers have to pay a carbon tax (Böhringer et al., 2012b). With a "price-based" BCA, there is no direct impact on the allowance market, unlike an "allowance-based" BCA under which importers are committed to buy some allowances and therefore influence their price.[14] This modeling choice implies adjusting the supply of allowances: the emission reduction objective in 2020 was applied to the sum of emissions generated by the sectors ETS in the EU and by products that are imported and consumed in the EU. The BCA makes it possible to target consumption-based emissions rather than production-based emissions.

The other elements of the BCA are defined in a more standard way (Manders and Veenendaal, 2008; Kuik and Hofkes, 2010; Böhringer et al., 2012b). The BCA applies only to imports of EITE goods. The evaluation of the number of allowances to surrender is based on the carbon content of imported products and varies with the country of origin. Finally, only direct emissions are taken into account.[15]

Considering a BCA applied irrespective of the origin of the imports and at the same time assuming that emission reduction pledges taken in Copenhagen are applied means some CO2 emissions have to be charged twice: once in the county that exports a CO2-emissive product to the EU or EFTA and once in the EU or EFTA. This double taxation may play against the BCA if a dispute related to it is raised at the WTO.

[13] In the BAU reference, India's emissions are under the cap corresponding to its commitment.
[14] For a comparison of a "tax-based" BCA and an "allowance-based" BCA, see Monjon and Quirion (2011).
[15] Böhringer et al. (2012b) also include indirect emissions.

**Table 2 – Quantitative pledges as of March 2010**

| Zone | Target year | Pledge | Reference year | Reference measure | Equivalent from 2005 emissions |
|---|---|---|---|---|---|
| USA | 2020 | -17% | 2005 | Level | -17.0% |
| Canada | 2020 | -17% | 2005 | Level | -17.0% |
| Japan | 2020 | -25% | 1990 | Level | -29.7% |
| Australia and New Zealand | – | | – | | -13.4% |
| Australia | 2020 | -5% | 2000 | Level | -11.0% |
| New Zealand | 2020 | -10% | 1990 | Level | -29.7% |
| Russian Federation | 2020 | -15% | 1990 | Level | +34.3% |
| Rest of Europe[a] | – | | – | | +40.1% |
| Belarus | 2020 | -5% | 1990 | Level | +57.1% |
| Croatia | 2020 | -5% | 1990 | Level | -1.2% |
| Moldova | 2020 | -25% | 1990 | Level | +221.3% |
| Brazil | 2020 | -36% | – | BAU | -18.4% |
| China and Hong Kong | 2020 | -40% | 2005 | Intensity | +69.7% |
| South Africa | 2025 | -30% | – | BAU | -15.2% |
| India | 2020 | -20% | 2005 | Intensity | +70.3%[c] |
| Other Countries[b] | – | | – | | |
| Indonesia | 2020 | -26% | – | BAU | N.A. |
| Mexico | 2020 | -30% | – | BAU | N.A. |
| Singapore | 2020 | -16% | – | BAU | N.A. |
| South Korea | 2020 | -30% | – | BAU | N.A. |
| Kazakhstan | 2020 | -15% | 1992 | Level | N.A. |

[a] Other countries in 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 level of emissions in 1992 (1990 data is not available). Due to non-availability of data, Moldova's reductions in emissions were computed using only CO2.

[b] These pledges are not implemented in our scenarios because they are part of much larger regions in the aggregation.

[c] MIRAGE-e projects that India will not bind the constraint.

*Source: IEA (2011), UNFCCC emissions data and authors' computations.*

### 2.3.3. The TR Scenario

Like the Hormones Case (Canada-EU-USA) concerning the EU ban on hormone-fed beef, the BCA, which concerns both domestic production and imports, could be considered as an obstacle to trade by a panel of potential complainants that experience exports losses to the EU. We limit the group of complainants to the countries individually represented in our aggregation. Despite the fact any WTO members can take the case to the Dispute Settlement Body (DSB) of the WTO, we assume that only large countries would find it profitable to do so, as they have the necessary financial and human resources (Breuss, 2003).

The complainants are Brazil, Canada, China, India, Japan, Russia, South Africa and the USA. This group is very heterogeneous as it includes developed and emerging economies, net fossil fuel exporters and net fossil fuel importers.

When designing trade retaliation, our strategy was inspired by previous cases for which some tariff increases have been authorized by the DSB,[16] and was not to establish an optimal reaction from the complainants. In the TR scenario, each complainant asks the DSB to authorize suspension of the application of Most Favored Nation (MFN) tariffs to the EU and its Member States. EFTA is considered as a follower and is consequently not concerned by retaliation.

Optimality could have been considered, for instance by imposing an endogenous retaliation for each country, seeking to maximize its utility or imposing exactly the same losses on the EU as those faced by the country as a result of the implementation of the BCA. However, this would have had two drawbacks. First, it does not correspond to previous cases, where the retaliations were rather decided on a political basis and without fine tuning of the retaliatory duty rate (see below); and where the implemented retaliation is computed based on the export losses a few years previously, due to the time required by the procedure. Second, the aggregation of retaliations by all the relevant countries is not likely to imply that European export losses would match the targeted amount, due to the possibility of worldwide trade deviations, especially between all the countries implementing retaliation.

Three elements have to be determined to define the retaliatory measures: the amount of retaliation that would be authorized by the DSB, the magnitude of tariff retaliation, and the list of products to which the measures would be applied.

A reciprocity approach is generally applied to determine the amount of retaliation. According to Bown and Ruta (2008), "complainant's permissible retaliation is to reduce the volume of the exports by an amount equal to the respondent's reduction of imports [...]" In the TR scenario, retaliation is applied to some trade flows whose amount equals the export losses due to the BCA. For instance, in the Hormones Case, the retaliating tariff is applied on an amount

[16] Namely the "EC – Hormones" case, the "US – Tax Treatment for 'Foreign Sales Corporations' " case or the "EC – Regime for the Importation, Sale and Distribution of Bananas" case (in the latter, only countervailing measures were used).

of trade equal to the difference between actual US or Canadian exports and the total import quota allocated to these countries by the EU.[17] The goal was to evaluate the export losses for the US and Canada, compared to a counterfactual (total available import quotas), the trickiest point being the determination of a fair counterfactual. In a CGE framework, the counterfactual is directly available. For that reason, we evaluate these losses as the difference in complainants' exports in the EITE sectors towards the EU between the BCA scenario and the ETS scenario.

Regarding the retaliatory tariff, WTO rules leave most of the decisions to the discretion of the retaliating country (Pauwelyn, 2010). As explained by Charnovitz (2001), the goal of trade retaliation is not to compensate exporters' losses, but to encourage compliance as explicitly described by the arbitrators in the Ecuador-EC Bananas case. To this end, these arbitrators advised that the complaining governments seek a suspension that is "strong". Like in the Hormones Case, we apply a duty of 100% on products we characterize as politically sensitive for the EU.[18] This retaliatory tariff is intended 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 in itself, but will in any case be higher than initially.

Regarding the list of products subject to retaliation, the selection process relies on the WTO "nullification and impairment" concept.[19] We chose a practical way of determining which products (HS6 level) are subject to an increase in tariffs.[20] The MAcMap-HS6 database (Guimbard et al., 2012) provides an ad valorem equivalent of 5,113 products for almost 170 importing countries versus 220 exporting countries. We merge tariff data with trade data between the EU and the complainants.[21] Focusing on agricultural products,[22] we exclude European products that benefit from free access to each complainant's markets and those that already face tariff equal to (or greater than) 100%. We sort the value of complainants' imports from the EU in descending order and stop when we match the total losses of complainant's export to the EU as given in MIRAGE-e simulations.

Trade retaliation is applied as early as 2016. We assume that complainants calculate their export losses to the European market during the year 2013 and take the case to the DSB the following

[17] EC – Hormones (US) (Article 22.6), paragraph III. E.

[18] In this case, the USA and Canada targeted European agricultural exports with 100% tariffs applied to a selected panel of products. In the "Foreign Sale Corporation" case, tariffs increased, starting at 5% and rising to 17%, but these tariffs were authorized to reach 100%.

[19] See http://www.wto.org/english/thewto_e/glossary_e/nullification_and_impairment_e.htm. Nullification and impairment concept is defined as "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".

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

[21] We use CEPII's dataset, named BACI, for the year 2009. It is a harmonized version of COMTRADE data at the HS6 level. See Gaulier and Zignago (2010).

[22] The first reason is that complainants' export losses on the EU market are generally lower than European exports to the complainant's market for only 2 HS6 products, leading to retaliation on only 1 HS6 products (or even 0). The second reason is that, for the EU, agriculture is apparently more politically sensitive than industry.

**Table 3 – Applied tariffs to the EU, in sectors subject to retaliation (initial and final, %)**

| Importer | Sector | Tariff applied | |
|---|---|---|---|
| | | Initial | Final |
| Brazil | Livestock | 4.6 | 11.9 |
| Canada | Industry | 6.2 | 6.2 |
| China HK | Industry | 5.6 | 5.7 |
| China HK | Livestock | 4.5 | 7.1 |
| India | Crops | 53.2 | 92.3 |
| India | Industry | 18.8 | 22.4 |
| India | Livestock | 16.0 | 47.8 |
| India | Chemical, rubber, plastic products | 15.8 | 16.3 |
| Japan | Industry | 4.6 | 4.7 |
| Russian Federation | Industry | 11.1 | 12.2 |
| South Africa | Industry | 6.6 | 7.2 |
| USA | Industry | 3.5 | 4.0 |

*Source: authors' calculations based on MAcMap-HS6.*

year. Settlement of a dispute takes around one year without appeal and one year and three months with appeal. We thus assume that the complainants raise the tariffs applied to the EU from 2016. Table 3 shows changes in the MIRAGE sectors in which retaliation occurs.[23] A constant level of retaliation is applied from 2016 to 2020.

Retaliation take place in a few sectors, due to the limited impact of BCA on trade flows in ETS sectors. For instance, China and USA raise their tariffs on a few HS6 lines (6 and 1, respectively) whereas India, whose trade flows with EU are smaller, will increase tariffs on 390 HS6 products, belonging to different aggregated sectors. Some of the sectors are significantly impacted by the protection applied.[24]

As the products are chosen separately from the model, there is no guarantee that European losses on the complainants' market, in 2013, will equal export losses due to BCA, in 2016 (when the increase in tariffs is implemented). Moreover, each country's retaliations are chosen independently from one another, meaning that general equilibrium effects may play in important role in determining relative choices.

[23] At the HS6 level, customs duties are thus identical (100%). Their aggregation at the MIRAGE level gives different sector weighted averages.
[24] Brazil: 1 HS6 line; Canada: 1 HS6 line; Russia: 4 HS6 lines; Japan: 1 HS6 line; South Africa: 1 HS6 line.

# 3. Results

## 3.1. A depressive effect of the BCA on exports in all sectors in the EU

Regarding EITE sectors, compared to the ETS scenario, the BCA would lead to a decrease in exports in almost every country or region (Table 4). In particular, it would penalize European exports. This is first explained by the decrease in the consumption of GHG-emissive products in EU27 and EFTA, resulting in fewer imports of these products. Exports that were intended for European markets before the implementation of the BCA would be directed towards other markets, and partly replace European exports.

**Table 4 – Variation in exports in the EITE sectors (2013)**

| Exporter | Scenario | |
|---|---|---|
| | ETS | BCA |
| EU27 | -0.83 | -1.92 |
| Brazil | -9.15 | -9.51 |
| Canada | -3.81 | -3.92 |
| China HK | -0.97 | -1.51 |
| India | 3.19 | 2.21 |
| Japan | -3.91 | -4.05 |
| Russian Federation | -4.74 | -5.9 |
| South Africa | -0.12 | -0.46 |
| USA | -2.65 | -3.19 |

Note: percent deviation from baseline, volume.
*Source: authors' calculations.*

In the EU, the BCA would also have a negative impact on exports in the majority of other sectors. For instance, in 2013, the decrease in exports from "Rest of Industry" would be respectively 0.98% and 1.37% (in volume) in the ETS scenario and in the BCA scenario.[25] Only the coal and gas sectors would increase their exports following the implementation of a BCA; this is explained by the decrease in the demand for these fossil fuels in the EU and EFTA.

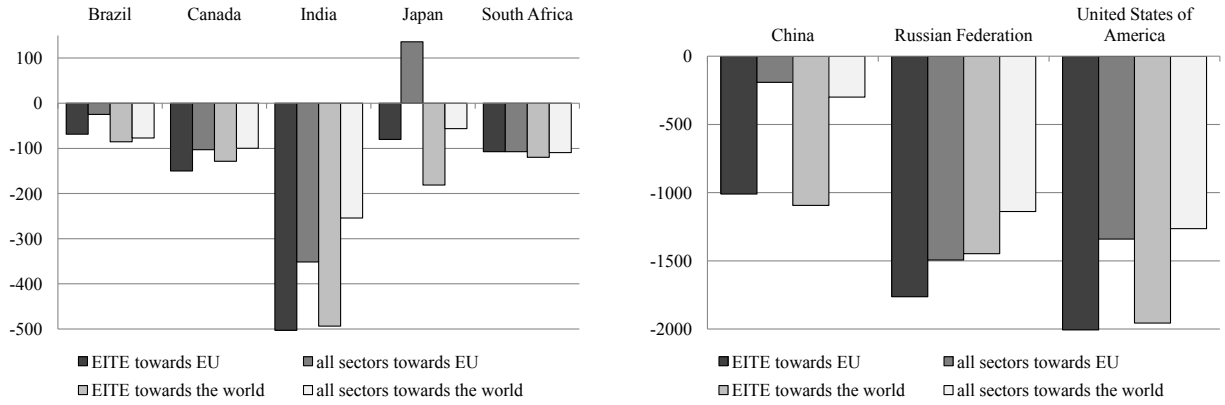
The picture is different in the rest of the world. The BCA would increase exports by some non-EITE sectors, in particular in "Rest of Industry" and "Services", in the majority of other countries. For instance, between the ETS and BCA scenarios, exports from the "Rest of Industry" would increase by 0.09% in China and 0.11% in USA, while those of "Services" would increase by 0.05% for each of these countries.

[25] See Table A.1 in the Appendix.

### 3.2. Impacts of trade retaliation

As mentioned in section 2.3.3, the amount of retaliation was chosen to be in accordance with past WTO decisions. However, this way of measuring export losses (only in the EITE sectors towards EU) does not take general equilibrium effects into account. As is apparent in Figure 1, export losses could be measured differently, which would frequently lead to lower export losses, in particular when all the sectors are taken into account. Indeed, as explained above, exports from some non-EITE sectors would benefit from the BCA implementation in the EU and EFTA.

**Figure 1 – Export losses induced by the BCA (2013)**




*Source: authors' calculations.*

*Note:* The two graphs do not use the same scale. Losses are calculated by difference between BCA and ETS scenario in million of 2004 USD, using FOB prices.

In any case, the extent of export losses in the EITE sectors towards EU differs greatly among retaliators: from almost 69 million USD in Brazil (0.6% of the value of its total exports) to 2,006 million USD in the USA (1.3% of the value of its exports) (Table 5). For some of the complainants, the amount of damages would be comparable with (or higher than) damages already identified by the WTO dispute settlement as a justification for retaliation. For instance, in the EC-USA-Canada beef hormones case, the recorded losses by the USA were evaluated at 116.8 million USD (11.3 million USD for Canada).[26]

The contribution of the different sectors to these losses also differs greatly depending on the country concerned. Nevertheless, the most impacted sectors are generally "Chemical, rubber, plastic products" (crp), "Ferrous metals" (i_s) and "Mineral products nce" (nmm) sectors. This reflects the relative weight of the sectors in total exports towards the EU from the different trade partners. For instance, in 2013, European demand for chemicals from Canada is around

[26] In the EU-USA Bananas case (1999), arbitrators determined that the level of nullification and impairment was 191.4 million USD per year. In the Foreign Sales Corporations case (EU-USA, 2000), export losses were evaluated at 4,000 million USD. Thus in the present study losses due to BCA are within this range.

**Table 5 – Export losses in EITE sectors induced by the BCA (2013)**

| Exporter | Export loss | Contribution of sector | | | |
|---|---|---|---|---|---|
| | | crp[a] | i_s[b] | nmm[c] | other[d] |
| | (1) | (2) | (3) | (4) | (5) |
| Brazil | 68.7 | 45.4 | 21.5 | 4.6 | 28.5 |
| Canada | 149.9 | 71.9 | 4.5 | 0.5 | 23.1 |
| China HK | 1,011.0 | 47.2 | 9.3 | 37.7 | 5.8 |
| India | 502.7 | 55.8 | 21.8 | 20.3 | 2.1 |
| Japan | 80.1 | 113.4 | -4.1 | -2.7 | -6.6 |
| Russian Federation | 1,763.5 | 51.8 | 29.0 | 0.6 | 18.6 |
| South Africa | 107.2 | 16.4 | 85.8 | 16.6 | -18.8 |
| USA | 2,006.1 | 91.8 | 0.4 | 2.2 | 5.6 |

[a] Chemical, rubber and plastic products
[b] Ferrous metals
[c] Mineral products nce
[d] Metals nce (nfm), Petroleum, coal products (p_c) and Paper products, publishing (ppp).
*Note*: Column (1) presents export losses for all EITE sectors, calculated by difference between BCA and ETS scenario (million of 2004 USD, FOB value). Column (2) to (5) present the contribution (%) of each EITE sector.
*Source: authors' calculations.*

six times greater than of the demand for imported ferrous metals and 17 times greater than imports of other mineral products, while European demand for South African ferrous metals is 11 times greater than European demand for other mineral products, and two times greater than EU demand for chemicals.

Like the BCA, trade retaliation has a depressive effect on international trade. In particular, retaliatory measures lead to a decrease in exports for the majority of retaliators (Table 6). EU exports are subject to the same changes.

The sectors with the biggest drop in exports are not the same as those in the BCA scenario, since tariff increases mainly target non-EITE sectors. Volumes of exports from EITE sectors remain stable at the world level in the BCA and TR scenarios but their production and trade flows are distributed differently.

In the EU, sectors targeted by trade retaliations would be subject to the biggest decreases in exports: -4.61% in the livestock sector, -2.26% in the "rest of the industry" and -1.94% in the "crops" sector. At the same time, production and exports of EITE sectors would be less reduced in the TR scenario. Both BCA and TR tend to limit the decrease in production in these sectors, whereas decreases in production in, and exports from, these sectors would occur in the majority of other countries.

BCA is often presented as a means of preserving competitiveness in energy-intensive sectors,

**Table 6 – Variations in exports (2016)**

| Exporter | Scenario | |
|---|---|---|
| | ETS | BCA |
| EU27 | -1.69 | -1.96 |
| Brazil | -2.57 | -2.52 |
| Canada | -0.71 | -0.68 |
| ChinaHK | -0.34 | -0.36 |
| India | 0.16 | -0.36 |
| Japan | -2.15 | -2.14 |
| Russian Federation | -1.10 | -1.35 |
| South Africa | -0.79 | -1.07 |
| USA | -1.01 | -1.12 |
| World | -0.67 | -0.72 |

Note: percent deviation from baseline, volume.
*Source: authors' calculations.*

interpreted as a limitation of production losses due to unequal carbon prices, and hence the preservation of employment in these sectors. Our results show that the trade measure would effectively limit production losses in the sectors targeted by the BCA. A more unexpected result is that trade retaliation would reinforce this effect (as can be seen in Table 7) because the EITE sectors are not targeted by the retaliations. However, this positive effect occurs at the expense of the non-EITE sectors. On the other hand, the BCA would lead to a decrease in production due to a drop in exports for other sectors, including the "Rest of Industry" and "Agriculture". This is a common result of a BCA in a CGE model (Manders and Veenendaal, 2008; Alexeeva-Talebi et al., 2008; Böhringer et al., 2012b). Once again, trade retaliation accentuates this trend.

In countries that implement retaliation, changes are limited, but contrasted between sectors. On the one hand, "Agriculture" and the "Rest of Industry" would see a slight increase in their production resulting from the deviation of trade flows from the EU towards local production, due to the retaliatory tariff. However, this effect would be offset by the loss of price-competitiveness due to the increase in the price of inputs. On the other hand, production in the EITE sectors tends to decrease marginally because they do not benefit from the trade diversion effect, whereas the price of their inputs would continue to increase.

### 3.3. Implications on macroeconomics and emissions

Up to now the analysis has focused on specific indicators of trade and production, whereas a more global snapshot of the economic and environmental consequences of political decisions is necessary. The simulated world real income changes associated with GDP variations are listed

**Table 7 – Differences in exports and production (2016)**

| Exporter | Sector | ETS Scenario | | BCA Scenario | | TR Scenario | |
|---|---|---|---|---|---|---|---|
| | | Prod. | Exports | Prod. | Exports | Prod. | Exports |
| EU27 | EITE sectors | -1.59 | -2.11 | -1.30 | -3.39 | -1.26 | -3.19 |
| | Agriculture | -0.25 | -0.87 | -0.38 | -1.10 | -0.47 | -3.13 |
| | Rest of Industry | -0.31 | -0.86 | -0.53 | -1.50 | -0.58 | -2.26 |
| China HK | EITE sectors | -0.20 | 0.96 | -0.24 | 0.23 | -0.25 | 0.20 |
| | Agriculture | -0.02 | -0.28 | -0.01 | -0.30 | 0.02 | -0.38 |
| | Rest of Industry | -0.19 | -0.59 | -0.13 | -0.46 | -0.14 | -0.48 |
| India | EITE sectors | 1.49 | 3.72 | 1.37 | 2.46 | 1.35 | 2.13 |
| | Agriculture | 0.05 | -1.12 | 0.06 | -1.03 | 0.10 | -1.57 |
| | Rest of Industry | -0.02 | -0.81 | 0.06 | -0.48 | 0.14 | -1.18 |
| Japan | EITE sectors | -3.45 | -6.97 | -3.46 | -7.11 | -3.46 | -7.12 |
| | Agriculture | -0.80 | -2.58 | -0.79 | -2.57 | -0.79 | -2.43 |
| | Rest of Industry | -0.49 | -1.05 | -0.48 | -1.00 | -0.47 | -0.98 |
| Russian Federation | EITE sectors | -1.68 | -0.99 | -2.23 | -2.74 | -2.30 | -3.03 |
| | Agriculture | 0.43 | 1.15 | 0.64 | 1.68 | 0.70 | 1.45 |
| | Rest of Industry | 0.21 | 1.15 | 0.69 | 2.41 | 1.22 | 1.16] |
| South Africa | EITE sectors | -1.01 | -0.26 | -1.07 | -0.67 | -1.13 | -0.84 |
| | Agriculture | 0.17 | 0.28 | 0.22 | 0.34 | 0.20 | 0.09 |
| | Rest of Industry | 0.30 | 1.15 | 0.38 | 1.36 | 0.48 | 0.69 |
| USA | EITE sectors | -2.15 | -2.54 | -2.22 | -3.29 | -2.23 | -3.36] |
| | Agriculture | -0.01 | -0.06 | 0.02 | -0.03 | 0.03 | -0.02 |
| | Rest of Industry | -0.11 | -0.13 | -0.05 | 0.05 | -0.02 | -0.11 |

*Notes*: percent deviation from baseline, volume. Agriculture includes the "Crops" and "Livestock" sectors.

*Source: authors' calculations.*

**Table 8 – World macroeconomic indicators and variations in emissions (2016 and 2020)**

| Variable | Scenario | | |
|---|---|---|---|
| | ETS | BCA | TR |
| World real income in 2016 | -0.14 | -0.15 | -0.15 |
| World real income in 2020 | -0.27 | -0.28 | -0.28 |
| World GDP (volume) in 2016 | -0.02 | -0.02 | -0.03 |
| World GDP (volume) in 2020 | -0.06 | -0.07 | -0.07 |
| World emissions in 2016 | -6.45 | -6.55 | -6.55 |
| World emissions in 2020 | -9.50 | -9.60 | -9.60 |

Note: percent deviation from baseline.
*Source: authors' calculations.*

below in Table 8.[27] This indicator provides more information than the GDP since it includes, among others, variations in terms of trade and allocation efficiency, but does not take into account the differences in the world emissions among the scenarios. Changes in real income must be compared to the expected benefits of limiting the increase in temperature. It is also interesting to understand the consequences of the trade measures envisaged (BCA and TR) in terms of variations in emissions. Table 8 also lists these changes in world emissions.

Results are given for 2016 and 2020: 2016 is the year in which the EU will decide whether it maintains the BCA, but this does not account for the dynamic impacts, for instance on sectoral capital accumulation. Due to the decreasing cap on emissions implemented, costs are also expected to increase progressively up to 2020. Then, the BCA would also become more costly, whereas the increases in the tariffs due to trade retaliation would remain the same. Nevertheless, even when the dynamic impacts in 2020 are taken into account, the macroeconomic picture only varies marginally at the world level, confirming that the impacts of the BCA and retaliatory measures would be of second order. The impact on world real income is slightly bigger than on world GDP.

Although the level of emissions worldwide is very similar in the three scenarios, the BCA would result in a slightly bigger decrease in the BCA and TR scenarios than in the ETS scenarios. There are two reasons for this difference. Firstly, the enlargement of the emission reduction perimeter to importers in the EU ETS reduces emissions by the EU and EFTA (see Table A.2 in the Appendix). Indeed emission reductions are allocated differently between sectors but also between domestic producers and importers. Domestic firms will reduce their emissions a little more than importers, particularly in our context where the intensity of foreign emissions is the basis for the BCA. Secondly, in the BCA scenario, emissions from countries which did not make pledges are also reduced, in particular due to the decrease in their exports of $CO_2$-intensive products, while emissions from countries with commitments remain stable. Finally,

[27]Variation in agents' real income is measured as an equivalent variation with respect to the BAU reference. Environmental valuation by households is therefore not taken into account.

**Table 9 – Differences in macroeconomic indicators (2020)**

| Country | ETS Scenario | | BCA Scenario | | TR Scenario | |
|---|---|---|---|---|---|---|
| | Real income | GDP | Real income | GDP | Real income | GDP |
| EU27 | -0.25 | -0.07 | -0.23 | -0.08 | -0.24 | -0.08 |
| Brazil | -1.56 | -0.26 | -1.57 | -0.26 | -1.56 | -0.26 |
| Canada | -0.41 | -0.03 | -0.42 | -0.04 | -0.42 | -0.04 |
| China HK | 0.07 | 0.13 | 0.08 | 0.13 | 0.08 | 0.13 |
| India | 0.52 | 0.30 | 0.50 | 0.29 | 0.50 | 0.28 |
| Japan | -0.43 | -0.25 | -0.43 | -0.25 | -0.43 | -0.25 |
| Russian Federation | -0.72 | -0.19 | -0.89 | -0.31 | -0.89 | -0.33 |
| South Africa | -0.32 | -0.13 | -0.34 | -0.14 | -0.32 | -0.15 |
| USA | -0.16 | 0.01 | -0.16 | 0.01 | -0.16 | 0.01 |

Note: percent deviation from baseline.
*Source: authors' calculations.*

trade retaliation would have no specific impact on world emissions.

Although marginal, the impacts of the different trade measures are of course more contrasted at the country level. Table 9 presents the results for the EU and for the countries that implement retaliations. Other regions are even less impacted by the different trade measures.

Once again, the countries are affected by bigger decreases in real income than in GDP, even though these variations remain small. In the EU, implementation of the BCA decreases the GDP even more than in the ETS scenario, while positively impacting its real income through an improvement in its terms of trade. Some countries see an improvement or no change in real income following the implementation of the BCA, thanks to gains in terms of trade, but the majority of the retaliators are affected negatively.

Logically, trade retaliation decreases European consumers' real income, but the drop remains below the one recorded in the ETS scenario, meaning that, for the EU, losses due to retaliation are not higher than gains due to BCA. Ultimately, European consumers enjoy a higher real income level and smaller world emissions in the TR scenario than in ETS scenario.

The implementation of trade retaliation has no significant impact on consumers' real income in retaliating countries. However, some of them (Brazil, South Africa) enjoy a positive impact of their action against the EU on their real income. Indeed, contrary to small open economies in which the optimal tariff is zero, implementing retaliation measures through additional tariff may improve the terms of trade of the countries concerned. In our scenario, these effects generally compensate for losses in allocation efficiency, even if they remain marginal.

## 4. Conclusion

Following the establishment of a BCA on imports of energy-intensive goods, the EU may be targeted by trade retaliation. For the EU and its partners, macroeconomic consequences (real income, GDP) are mainly driven by the implementation of climate policies to decrease their emissions (ETS scenario), compared to a BAU scenario. Nevertheless, the export losses suffered by the EU's trade partners due to the BCA would be sufficient to lead to a WTO dispute: we show that losses would mainly affect China, the US and Russia, with order of magnitudes ranging between 1 and 2 billion US dollars in the first year of implementation of the trade measure. The possible ensuing trade retaliations against the EU would mainly harm agricultural goods, with additional export losses of more than 500 million dollars, but the production losses of these sectors would be lower. However, BCA allows European producers of EITE sectors to suffer less from international competition and carbon pricing while reducing worldwide carbon emissions. Its implementation is positive for the EU compared to the ETS scenario at the expense of most of its partners. These partners punish the EU by using prohibitive duties at the product level. Previous retaliation cases suggest that, in this case, European agriculture will be the first target, but the impacts will also be of second order (as in other previous cases of trade retaliation) at the macroeconomic level. A political Cornelian choice might therefore be at stake on the European side: reconciling global climate issues and protection of its own agriculture.

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# Appendix

**Table A.1 – Differences in exports in EU27 (percent deviation from baseline, volume, 2013 and 2016**

| Sector | 2013 | | 2016 | |
|---|---|---|---|---|
| | ETS | BCA | BCA | TR |
| Coal | 9.74 | 11.23 | 26.76 | 26.97 |
| Crops | -1.61 | -1.87 | -1.64 | -1.94 |
| Chemical, rubber, plastic products | -0.19 | -1.46 | -2.88 | -2.68 |
| Electricity | -13.57 | -15.63 | -27.00 | -26.78 |
| Gas | 38.24 | 41.23 | 34.41 | 34.73 |
| Ferrous metals | -1.65 | -2.99 | -5.14 | -4.85 |
| Rest of industry | -0.98 | -1.37 | -1.50 | -2.26 |
| Livestock | -0.66 | -0.73 | -0.42 | -4.61 |
| Metals nce | -0.68 | -1.78 | -4.03 | -3.70 |
| Mineral products nce | -1.65 | -2.56 | -4.07 | -3.81 |
| Oil | -4.88 | -5.06 | -5.67 | -5.66 |
| Other extraction | -0.01 | -0.22 | -0.09 | -0.03 |
| Petroleum, coal products | -1.25 | -1.41 | -1.87 | -1.86 |
| Paper products, publishing | -1.16 | -1.59 | -1.97 | -1.68 |
| Services | -0.83 | -1.09 | -0.73 | -0.46 |
| Transport | -1.43 | -1.61 | -1.03 | -0.84 |

*Source: authors' calculations.*

**Table A.2 – Reduction in emissions (percent deviation from baseline, 2020)**

| Sector | ETS | BCA | TR |
|---|---|---|---|
| EU27 | -19.90 | -20.45 | -20.44 |
| EFTA | -10.23 | -10.40 | -10.39 |
| USA | -16.03 | – | |
| Canada | -20.88 | – | |
| Japan | -25.85 | – | |
| ANZ | -32.14 | – | |
| Russian Federation | -3.24 | – | |
| Rest of Europe | -1.32 | – | |
| Brazil | -36.00 | – | |
| China HK | -10.86 | – | |
| South Africa | -22.50 | – | |
| India | 0.44 | 0.34 | 0.34 |
| Oil producing countries | 2.08 | 1.73 | 1.72 |
| Other Latin America | 3.76 | 3.79 | 3.78 |
| Other south-east Asia | 4.01 | 3.87 | 3.85 |
| LDC | 4.18 | 4.05 | 4.05 |
| Rest of the world | 4.01 | 4.00 | 3.99 |
| World | -9.499 | -9.597 | -9.598 |

Note: A dash denotes no variation compared to ETS scenarios.

*Source: authors' calculations.*