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Alternative border-carbon-adjustment mechanisms in the European Union and responses: aggregate and within-coalition results

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1. Introduction

The Paris Agreement (UNFCCC 2015) has led to a globally shared long-term temperature goal. Within the multilateral agreement, each country can unilaterally decide its greenhouse gas (GHG) emissions reduction targets. Many countries' original Nationally Determined Contributions (NDCs) are deemed insufficient for achieving the Paris Agreement goals (Rogelj et al. 2016, Vandyck et al. 2016), and even more recent targets are not expected to reduce emissions enough to limit the temperature increase to 1.5°C above pre-industrial levels (UNFCCC 2021). This portrays a fragmented global climate policy context, with some international actors more ambitious than others. The imbalances in climate change mitigation ambition across regions can result in carbon leakage, i.e. the decrease in GHG emissions in a given country can partially be offset by the increase in emissions in other regions (Carbone and Rivers 2017, Branger and Quirion 2014). Border carbon adjustment (BCA)^a mechanisms are shown to reduce carbon leakage rates (Böhringer, Balistreri, and Rutherford 2012, Branger and Quirion 2014). To date, only California has implemented a BCA mechanism, covering electricity imports from other USA States, Mexico and Canada (Pauer 2018). Similar measures have been suggested by policymakers in the past, but never actually implemented (Sapir and Horn 2020, Prag 2020). In fact, even though BCA mechanisms are shown to contain carbon leakage, there are potential legal, technical and diplomatic drawbacks (Cosbey et al. 2019, Marcu, Mehling, and Cosbey 2020) that need to be weighed against the environmental and competitiveness benefits.

The European Union (EU) plans to curb its GHG emissions by 55% by 2030, relative to 1990 (European Commission 2019, European Council 2020), increasing its ambition from its previous goal of 40% reductions compared to 1990 (European Council 2015). The European Commission is evaluating whether to implement a BCA by the end of 2023 to “level the playing field” for emission-intensive trade-exposed (EITE) sectors, in connection with its European Green Deal proposal (European Commission 2019). Depending on its design, in combination with climate policies, the BCA will affect not only trade between the EU and the rest of the world, but also production, consumption and trade patterns within the EU. This, in turn, will determine the level of acceptance of this measure by the MSs and their commitments to the EU-wide climate goals. In addition, if the European Commission scopes the BCA to resolve disagreements between its MSs or if the measure is seen as a purely protectionist intervention (i.e. protecting EU industries' competitiveness with little or no environmental gains), such

^a Also referred to as “Carbon Border Adjustment (CBAM)” or “Carbon Border Tax (CBT)” in the literature.

action may lead to retaliations from other countries. Instead of retaliating, non-EU regions could also react by increasing their carbon prices to avoid aggregate carbon leakage from the EU, reducing the policy space for the EU to implement a BCA on environmental grounds.

An adverse reaction from international actors to a BCA, generally in the form of retaliatory trade measures, is often mentioned in the literature. However, few studies analyze this possibility numerically (Böhringer, Carbone, and Rutherford 2016, Fouré, Guimbard, and Monjon 2016). While providing valuable insights on the strategic use of BCAs and on potential retaliatory measures, these studies leave room for further research. They are based on decarbonization goals not in line with the current NDCs and on a different international trade environment. Also, they do not consider non-CO₂ emissions (that account for 27.3% of global GHG emissions in 2014 (Aguiar et al. 2019, Chepeliev 2020a) and are linked to other drivers than CO₂ emissions) and do not model electricity generation technologies directly, which would improve the representation of flexibilities to achieve the climate goals in the model. Additionally, these studies do not provide detailed insights on the results within a small (in terms of global shares of GHG emissions) coalition of countries reducing GHG emissions unilaterally.

In this study, we use a recursive dynamic computable general equilibrium (CGE) model to evaluate how two alternative EU BCAs and three reactions from non-EU trade partners affect emissions, output and trade flows. We present results for EU and non-EU aggregates, and for eight EU countries/regions. We simulate six scenarios and compare them against a baseline between 2014 and 2030. The first scenario simulates an increase in EU mitigation targets in line with the EU Green Deal goal. The other scenarios build upon the first one. The second and third scenarios simulate two alternative BCA mechanisms implemented by the EU on non-EU EITE imports. The fourth and fifth scenarios assume reciprocal bilateral BCAs imposed by non-EU regions on imports from the EU, building on the third scenario. The sixth scenario simulates that non-EU regions keep their emissions fixed to the baseline level, implying zero aggregate carbon leakage from EU to non-EU regions due to the EU Green Deal.

We contribute to the literature debate on border carbon adjustment by analyzing potential retaliatory or cooperative behaviors by international actors and within-coalition results. Compared to studies on a similar topic, we use updated climate pledges and the recently proposed EU Green Deal to design our scenarios. We also model non-CO₂ emissions and directly characterize the production of electricity from renewable and other sources in our CGE model. Finally, by evaluating within-coalition and sector-specific results, we are able to capture how internal and external stakeholders can potentially influence the climate policy of a coalition (i.e. the EU).

2. Methods and scenarios

2.1 Model and database

The research is performed using a modified version of the model GTAP-E-RD, a multi-regional multi-sectoral recursive dynamics CGE model. The model is built by integrating GTAP-E (Burniaux and Truong 2002, McDougall and Golub 2007), an energy-oriented version of the widely used standard GTAP model (Hertel et al. 1997, Corong et al. 2017), and the GTAP-RD model (Aguiar, Corong, and van der Mensbrugghe 2019).

We use the GTAP Power V10 database (Chepeliev 2020b) and the GTAP non-CO₂ V10 database (Chepeliev 2020a). We model 16 regions and 16 commodities (Table 1). The 16 commodities are generated by 17 sectors. Electricity is generated by two aggregated sectors: electricity from renewable sources, and electricity from fossil fuels and nuclear. Any other commodity, instead, is produced by a homonymous sector (e.g. the *coal* commodity is produced by the *coal* sector). The regional

aggregation has been selected to represent the EU MSs with the highest GDP and groups of other relevant members, and the main EU partners and biggest international emitters^b. The sectoral and commodity aggregation has been chosen to represent the sectors most exposed to carbon leakage (i.e. the EITE sectors: *chemicals and chemical products, non-metallic mineral products, iron and steel products, non-ferrous metals*), the energy sectors (*coal, oil, gas, oil products, electricity*) and the rest of the economy.

Table 1 – Regional and commodity aggregation of the two datasets.

Regions	Commodities
Germany	Agriculture and Food (AgrFood)
France	Coal
Italy	Oil
Spain	Gas
Belgium, Netherlands, Luxembourg (BeNeLux)	Oil Products (Oil_Pcts)
Denmark, Sweden, Finland (Nordic_EU)	Electricity (ely)
Czech Republic, Hungary, Poland, Slovakia (Visegrad)	Chemicals and chemical products (chm)
Rest of EU	Pharmaceutical products (bph)
UK	Rubber and plastic products (rpp)
USA	Non-metallic mineral products (nmm)
China	Iron & Steel products (i_s)
India	Non-Ferrous Metals (nfm)
Japan	Other industries (oth_ind)
Brazil	Utilities (Utl)
Russia	Transport (Transp)
Rest of the World (ROW)	Services (Ser)

In the model, similarly to Dixon and Rimmer (2002), we introduce a twist specification in the non-diagonal make matrix, to target in the baseline exogenous changes to electricity generated by renewable sources (and endogenously modify the quantity of electricity produced from other sources, to match the total electricity demand). We add equations to integrate the GTAP v10 non-CO2 database (Chepeliev 2020a) and capture relevant GHG trends. We include non-CO2 emissions in the economy-wide emission trading system (ETS) that in the standard GTAP-E-RD. Two additional ETSs are also added to the model. They allow the model user to target reductions of GHG emissions in user-selected parts of the economy of one or more regions. For the scope of this study, one ETS targets reductions in *Agriculture and Food, Utilities, Transport and Services* sectors and emissions from private transport and residential buildings (linked to private households in the GTAP datasets) in individual EU MSs (i.e. emission trading between sectors but not between countries). The other ETS targets reductions in the remaining industrial and power sectors, allowing emission trading between sectors and between EU members. The two ETSs we implement at the EU level broadly mimic the Effort Sharing Decision (European Parliament and European Council 2009) and the EU ETS (European Parliament and European Council 2003)^c. Finally, we design nine alternative border carbon adjustment mechanisms that allow to implement carbon prices on imports, based on (1) scope 1 emission intensity of a given commodity imported and region, (2) average world scope 1 emission intensity of a given commodity, (3) average EU scope 1 emission intensity of a given commodity, (4) average scope 1 emission intensity of a given commodity produced in non-EU regions, (5) scope 1 and scope 2 emission intensity of a given commodity in any region, (6) average world scope 1 and scope 2 emission intensity of a given

^b Based on our calculations using the GTAP v10 and the GTAP non-CO2 v10 databases, in 2014 all regions except ROW account for 66% of global GHG emissions.

^c Representing the sectoral coverage of the EU ETS and the EU ESD, without hindering the computability of scenarios, is not an easy task. The data sources granularity (75 sectors in GTAP Power and 65 in GTAP non-CO2) does not allow for a perfect correspondence. Hence, some assumptions were needed, e.g. air transport aggregated in the *Transp* sector and included in the EU ESD policy.

commodity, (7) average EU scope 1 and scope 2 emission intensity of a given commodity, (8) average scope 1 and scope 2 emission intensity of a given commodity produced in non-EU regions, (9) average world scope 1 and regional scope 2 emission intensities of a given commodity.

2.2 Baseline

The databases, of which the base year is 2014, are updated to recreate a baseline towards 2030 in annualized steps. In our baseline, we target population and labor force projections consistent with the ‘middle of the road’ Shared Socioeconomic Pathway (SSP2) (Fricko et al. 2017, Kc and Lutz 2017), differential sectoral productivities (Bekkers et al. 2019), and autonomous energy efficiency improvements across countries and industries (1.5% yearly growth). GDP growth is also exogenously defined by endogenizing regional labor productivity and is consistent with historical data between 2014 and 2019, with post-COVID-19 forecasts between 2020 and 2025 (IMF 2020), and with SSP2 projections between 2026 and 2030 (Dellink et al. 2017). GHG emissions generated by the sectors covered by the EU ETS in the EU are exogenously targeted from 2015 to 2019, and from 2022 to 2030. Between 2015 and 2019, we target country-specific verified emissions for the covered sectors (EEA 2020), for the eight individual EU regions and the UK. From 2022, we impose an EU-wide linear annual reductions in available emission permits by 2.2% (European Commission 2015). We also target GHG emissions in sectors covered by the EU ESD between 2015 and 2019, and from 2022 and 2030. From 2015 to 2018, we use historical data for EU members and the UK (Eurostat 2020). Changes in 2019 are obtained assuming a linear reduction in 2019 to achieve the 2020 targets (European Parliament and European Council 2009). Targets from 2022 for individual EU members are calculated using a constant yearly reduction rate between 2020 and 2030 to achieve the 2030 EU ESD targets (European Parliament and European Council 2018). Changes in total GHG emissions in non-EU regions (including the UK from 2022) follow median CD-Links^d multi-model projections (Roelfsema et al. 2020) in the *NDCi* scenario, i.e. consistent with goals to which countries/regions have committed to in their NDC documents and with policies implemented to achieve them. Changes in CO₂ emissions in 2020 due to the effect of COVID-19 are targeted using data from Carbon Monitor (Liu, Ciais, Deng, Davis, et al. 2020, Liu, Ciais, Deng, Lei, et al. 2020); in 2021, CO₂ emissions are assumed to rebound^e. The output of renewable electricity in each country is also exogenously set. Between 2015 and 2019, we use data from Ritchie (2021) for each individual region. For 2020, we use historical data from EMBER (Redl et al. 2021) for EU regions, and median CD-Links projections for non-EU regions (Roelfsema et al. 2020). From 2021 onwards, for EU members, we target recent projections in line with their National Energy & Climate Plans (Moore et al. 2020), and median CD-Links projections for non-EU regions (Roelfsema et al. 2020). Finally, we assume a yearly decrease in iceberg trade costs between all regions by 0.5% (Bekkers et al. 2020), and an increase in the bidirectional trade costs between the EU and the UK in 2021 by 3% (Boulanger and Philippidis 2015)^f.

^d CD-LINKS Scenario Explorer hosted by IIASA (release 2.0). Available at: <https://data.ene.iiasa.ac.at/cd-links/#/>

^e In 2020, CO₂ emissions are reduced in all regions except China. In 2021, we assume a rebound in CO₂ emissions in all regions (i.e. an increase equal to the percentage change decrease in 2020) except China, which increases its CO₂ emissions at the same rate as 2020. Additionally, we keep non-CO₂ emissions endogenous in 2020 and 2021, due to lack of available data and forecasts. The non-CO₂ emissions are observed to follow changes in line with GDP changes in these two years.

^f Boulanger and Philippidis (2015) model an increase in iceberg costs between 2% (lower limit) and 5% (upper limit).

2.3 Scenarios

Against this baseline, six scenarios are modeled (Table 2).

Table 2 – Scenarios simulated

	<i>EUGD</i>	<i>EUGD_BCA1</i>	<i>EUGD_BCA2</i>	<i>EUGD_BCA2_R1</i>	<i>EUGD_BCA2_R1</i>	<i>EUGD_C1</i>
Percentage change in EU GHG emissions vs baseline, 2030	-23.75%	-23.75%	-23.75%	-23.75%	-23.75%	-23.75%
Percentage change in non-EU GHG emissions vs baseline, 2030	endogenous	endogenous	endogenous	endogenous	endogenous	fixed to baseline levels, i.e. 0%
Carbon price in non-EU regions	fixed to baseline levels	fixed to baseline levels	fixed to baseline levels	fixed to baseline levels	fixed to baseline levels	endogenous
EU BCA on imports from non-EU regions, starting in 2023	none	EU average carbon price in ETS sectors, for EITE imports, based on EU sectoral emission intensity (scope 1)	EU average carbon price in ETS sectors, for EITE imports, based on each region and sector emission intensity (scope 1 and 2)	EU average carbon price in ETS sectors, for EITE imports, based on each region and sector emission intensity (scope 1 and 2)	EU average carbon price in ETS sectors, for EITE imports, based on each region and sector emission intensity (scope 1 and 2)	none
non-EU BCA on imports from EU, starting in 2023	none	none	none	Same price as EU, based on EU average sector emission intensity (scope 1 and 2)	Same price as EU, based on EU individual members' sector emission intensity (scope 1 and 2)	none

In the first scenario (*EUGD*), we simulate an increase in climate efforts in the EU starting in 2022, in line with the EU Green Deal goals (European Commission 2019, European Council 2020). We assume a reduction in emissions by 2030 in EU by 55% compared to 1990. To achieve such a reduction, we model an increase in efforts in the EU-wide EU ETS yearly reductions (from 2.2% per year in the baseline to 5.28% in *EUGD*). We also model changes to the ESD targets for each EU country/region. The emissions in these sectors change yearly between -4.82% and -5.92%, compared to the baseline range that was -1.94% / -3.22%. Carbon prices in the EU are endogenously defined as model solutions. Carbon prices in non-EU regions are fixed to the baseline levels, whereas GHG emissions are computed endogenously.

The second scenario (*EUGD_BCA1*) builds upon the first one. In addition to reductions in EU emissions (as in the *EUGD* scenario), we add a BCA on EU imports from non-EU regions starting in 2023. The BCA applies to imports of EITE commodities (*chemicals and chemical products, non-metallic mineral products, iron and steel products, non-ferrous metals*). The carbon price for each ton of CO₂e embedded in imports is based on the EU ETS price in the *EUGD* scenario, increasing each year. The carbon price following changes in the EU ETS prices is in line with the so-called 'notional ETS', which has been mentioned as a potential BCA mechanism by scholars and EU officials. In this scenario, we implement a uniform BCA across countries, based on EU's average direct emission intensities in each industry in each year. This BCA is in line with the WTO Most Favored Nation (MFN) principle, as all non-EU regions face the same increase in import tariffs. This BCA is also expected to place a lower administrative burden on the EU, as EU emissions intensities are easier to calculate than non-EU ones, since non-EU producers or countries do not have these data or might decide not to disclose them. The

BCA is modeled as an intermediate scenario between the “play-it-safe” and “most probable” design in Marcu, Mehling, and Cosbey (2020).

In the third scenario (*EUGD_BCA2*), in addition to the implementation of the EU Green Deal as in the first scenario, the EU levies a BCA on EITE imports starting in 2023. The BCA covers scope 1 and scope 2 GHG emissions embodied in EITE imports, discriminating across countries and sectors with respect to both scope 1 and scope 2 emissions. The design of this BCA is more aggressive than the previous one, as it targets individual non-EU countries (that on average have higher emission intensities than the EU) and includes emissions from electricity generated to be used for the production of the targeted commodities. Therefore, this BCA mechanism is more likely to tackle competitiveness issues on the domestic market. However, the embodied emissions of each good in non-EU countries are difficult to calculate and, more importantly, this BCA design risks not to be accepted by non-EU countries as it violates the MFN principle (tariff rates faced for the same good by individual non-EU countries will be different, as emission intensities differ).

Therefore, we simulate two additional scenarios (*EUGD_BCA2_R1* and *EUGD_BCA2_R2*), to evaluate the effects of retaliatory BCAs on non-EU imports from the EU. Both build on the third scenario (*EUGD_BCA2*), and both adopt the EU ETS carbon price. In *EUGD_BCA2_R1* non-EU regions’ BCAs target imports of EITE products from the EU, based on the average EU emission intensity (scope 1 and scope 2) of each product. In *EUGD_BCA2_R2* non-EU regions’ BCAs are based on the individual EU members’ emission intensities (scope 1 and scope 2) of each commodity. This scenarios are designed to evaluate impacts of potential retaliation, which is often mentioned as one of the main concerns in the literature.

Finally, we simulate a scenario in which, in addition to the implementation of the EU Green Deal in the EU, non-EU regions’ emissions do not increase compared to the baseline (*EUGD_C1*). In this scenario, the aggregate carbon leakage rate is zero by assumption, but can be different at the sectoral level.

3. Preliminary results

As this study is still ongoing, the results shown below are obtained from preliminary simulations.

We present in this section key simulation results. This section is split into three parts. We first present global and EU aggregate GHG and GDP impacts. Second, we show the effects on EU aggregate sectoral outputs, emissions and trade flows. Finally, we present the within-EU sectoral impacts.

3.1 Aggregate results

Implementing the EU Green Deal using carbon pricing instruments (i.e. *EUGD* scenario) reduces global GHG emissions by 0.85% in 2030, compared to the baseline (Figure 1). The EU cumulative carbon leakage rate is 46.4%. The introduction of an EU BCA on EITE imports based on EU average sectoral emission intensities (i.e. *EUGD_BCA1* scenario) leads to slightly lower global emissions (-0.86%) and leakage rate (45.5%). A BCA based on individual non-EU countries’ emission intensities that accounts for scope 1 and 2 emissions (*EUGD_BCA2* scenario) has a stronger impact on global emissions (-0.94%), with a lower leakage rate (40.7%). Both BCAs reduce global emissions and carbon leakage, but decreases in *EUGD_BCA2* scenario are higher. This is due to the fact that in *EUGD_BCA2* the uniform GHG price is implemented against individual emission intensities which on average are higher in non-EU countries than in EU and also accounts for emissions caused by the electricity generation sector, proportionally to electricity use by each EITE sector (the electricity sector in EU is cleaner than in non-EU countries, on average). The implementation by non-EU regions of BCAs on imports from the EU, based on average EU EITE sectors’ emission intensities (*EUGD_BCA2_R1*) or on individual EU regions’

emission intensities (*EUGD_BCA2_R2*) lead to virtually identical global emission reductions (-0.91%) and carbon leakage rate (42.6%). Compared to *EUGD_BCA2*, upon which the two scenarios are built, the global emission reductions are lower, as the non-EU BCAs directly protect non-EU EITE industries from EU competition on their domestic markets. Finally, when non-EU regions cooperate (i.e. emissions in non-EU regions are fixed to the baseline level, implying no aggregate carbon leakage by assumption), we observe the highest reduction in global GHG emissions, by -1.58% by 2030 (scenario *EUGD_C1*).

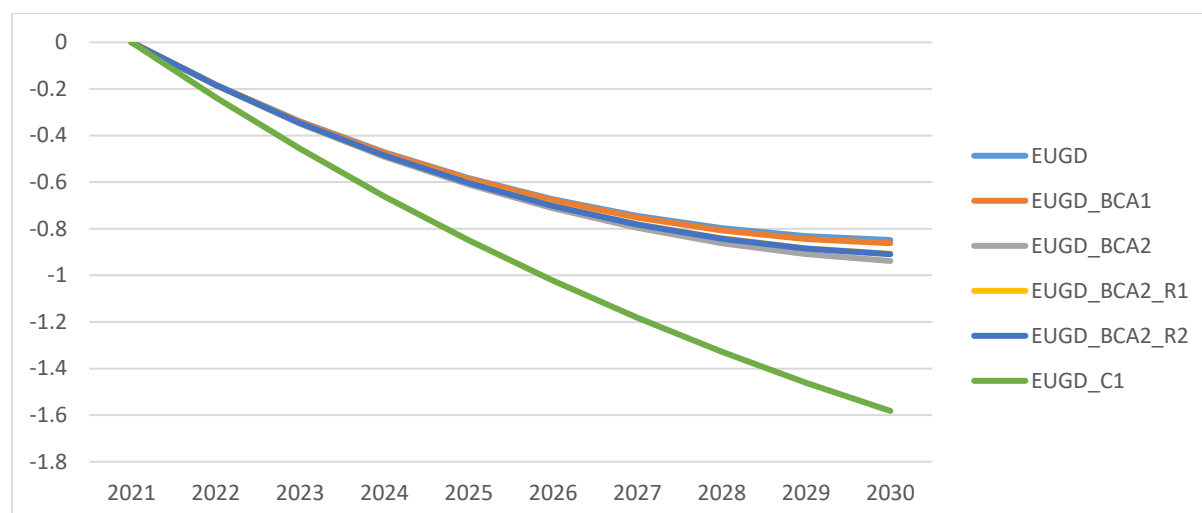


Figure 1 – Cumulative change in global GHG emissions, relative to the baseline (%)

In all scenarios, we observe a decrease in EU GDP and small increases in non-EU regions' GDP by 2030, compared to the baseline (Table 3), driven by the implementation of mitigation policies in the EU. EU BCAs acts as a protectionist measure, leading to allocation inefficiencies and pushing down EU and non-EU GDP, compared to *EUGD*. BCAs on EU EITE exports to non-EU regions further reduce EU GDP, and increase non-EU GDP, leading to a less lowered global GDP compared to *EUGD*. Finally, limited cooperation from non-EU regions (*EUGD_C1*) shows a lower cumulative decrease in EU GDP in 2030 (-3.087%), but also a lower cumulative decrease in non-EU GDP in 2030 (0.099%), partially shifting the mitigation burden from EU to non-EU regions but leading to the highest reduction in GDP compared to the baseline (-0.454%).^g

Table 3 – Cumulative change by 2030 in EU, non-EU and global real GDP, relative to the baseline (%)

	<i>EUGD</i>	<i>EUGD_BCA1</i>	<i>EUGD_BCA2</i>	<i>EUGD_BCA2_R1</i>	<i>EUGD_BCA2_R2</i>	<i>EUGD_C1</i>
EU	-3.107	-3.114	-3.149	-3.155	-3.152	-3.087
non-EU	0.161	0.160	0.157	0.159	0.159	0.099
World	-0.406	-0.409	-0.419	-0.416	-0.416	-0.454

3.2 Sectoral results

The effects of the EU Green Deal and of the related trade policy measures on economy-wide aggregates are driven by changes in the sectors affected the most by these policies, i.e. the EITE sectors. The implementation of the EU Green Deal (*EUGD*) without additional trade policy measures

^g In this study, we do not account for environmental and other (e.g. health) benefits obtained by reduced GHG emissions. In addition, the taxes and tariffs revenues are transferred lump-sum to the regional household; instead, they could be re-invested in e.g. regional or global green technology funds (boosting productivity or alleviating potential distributional drawbacks across countries).

supporting it reduces the EITE output in the EU by 3.52% by 2030 compared to the baseline (Figure 2). This is due to reduced competitiveness of EU EITE producers both on domestic and international markets, due to the sectors being affected directly by EU ETS prices and indirectly by changes in energy prices. In fact, in the *EUGD* scenario, EU EITE imports from non-EU regions increase by 1.07%, and EU EITE exports to non-EU regions decrease by 3.86%. In *EUGD_BCA1* and *EUGD_BCA2*, we observe a reduction in imports from non-EU regions (by 4.37% and by 16.74%, respectively), due to the BCAs effectively acting as import tariffs. The EITE industries are protected in the domestic market as part of the imported supply is replaced by domestically produced EITE goods. However, EU EITE exports are reduced by 5% and 7.4%, respectively. The export losses compared to *EUGD* are due to increased trade in EITE goods between non-EU regions. As a consequence, we observe reductions in EITE output by 2.63% in *EUGD_BCA1* and by 0.25% in *EUGD_BCA2*. The introduction of retaliatory BCAs from non-EU regions on EU exports further push down EU exports (by 15.22% in *EUGD_BCA2_R1* and by 14.88% in *EUGD_BCA2_R2*) and imports (by 18.17% and by 18.12%, respectively), due to additional trade integration between non-EU countries. This lowers EU EITE output (by 2.27% and by 2.17%, respectively). Hence, the output of the EU EITE sector under the more aggressive BCA (*EUGD_BCA2*), even when facing retaliation, is higher than in *EUGD* and *EUGD_BCA1*. Finally, in *EUGD_C1* we observe similar results and mechanisms than in *EUGD*, with a slight shift of the sectoral mitigation burden towards non-EU regions but no direct protection of the EU EITE sectors.

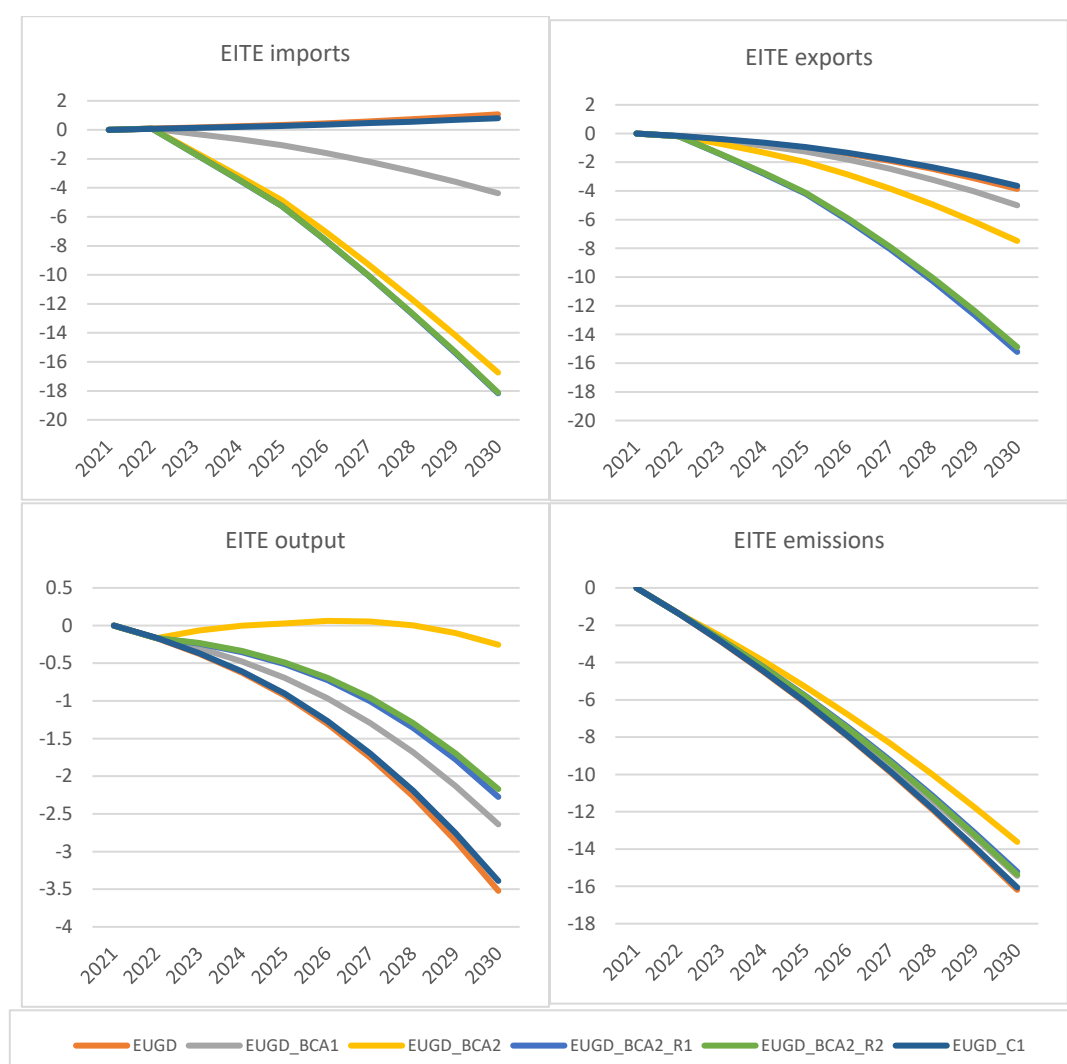


Figure 2 – Cumulative change in EU EITE imports from non-EU regions, EU EITE exports to non-EU regions, EU EITE output, EU EITE GHG emissions, compared to the baseline (%)

GHG emissions from EU EITE sectors are abated in all scenarios more than the changes in output, indicating significant reductions in EU EITE GHG intensities (Figure 2). The ranking of EITE sectors' GHG reductions across scenarios follows the reductions in output. In *EUGD*, the 16.2% reduction in the EU by 2030 leads to a carbon leakage rate for EITE sectors of 85%, leading to low emission reductions for the EITE sectors globally, by 0.14% (Table 4). Similarly to the aggregate regional carbon leakage (Figure 1), carbon leakage for EITE sectors is reduced more in *EUGD_BCA2* (10%) than *EUGD_BCA1* (75%), due to the fact that in the latter scenario the BCA targets emission intensities of individual non-EU countries EITE sectors, instead of using EU's as a benchmark. The GHG emission abatement in EITE industries is reduced in the EU, partially shifting the burden to non-EU regions, with sectoral global emissions being lower than in *EUGD*. Non-EU regions can protect their EITE industries by implementing retaliatory BCAs on the EU, increasing their output and consequently emissions and EU EITE carbon leakage in *EUGD_BCA2_R1* and *EUGD_BCA2_R2*, compared to *EUGD_BCA2*. Finally, an increase in carbon prices in non-EU regions to keep their total regional emissions equal to the baseline (i.e. zero aggregate carbon leakage), leads to a carbon leakage for EITE sectors of 15%, but reducing emissions the most globally in 2030 by 0.74%.^h While in *EUGD_C1* there is no carbon leakage at the aggregate level, leakages can still occur at the sectoral level. In this specific case, to keep emissions fixed at the baseline level, most of the reductions compared to *EUGD* in *EUGD_C1* are carried out in the electricity generation sector and in transport.

Table 4 – Cumulative change in 2030 in GHG emissions from EITE sectors in EU, non-EU and world aggregates, relative to baseline (%); carbon leakage rates

	<i>EUGD</i>	<i>EUGD_BCA1</i>	<i>EUGD_BCA2</i>	<i>EUGD_BCA2_R1</i>	<i>EUGD_BCA2_R2</i>	<i>EUGD_C1</i>
EU	-16.19	-15.44	-13.62	-15.22	-15.36	-16.06
non-EU	0.79	0.67	0.08	0.35	0.34	0.14
World	-0.14	-0.21	-0.66	-0.50	-0.52	-0.74
Carbon leakage	85%	75%	10%	40%	38%	15%

3.3 Within-EU results

To be added

4. Conclusions

To be added

^h The carbon leakage rate in *EUGD_C1* (15%) is higher than *EUGD_BCA2* (10%). However, the emission reductions in the EU and globally in *EUGD_C1* are higher than all other scenarios (except *EUGD* for EU). This is due to the fact that carbon leakage is a relative measure, being it affected by both the numerator (i.e. change in non-EU EITE emissions) and the denominator (i.e. absolute change in EU EITE emissions).

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