EU Carbon Border Adjustment with the US Rejoining Paris: A Bit of a Game Changer*

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Abstract

The new European Commission in office since December 2019 has announced that the EU will be climate neutral by 2050. A series of measures of the proposed "European Green Deal" will back this ambition, and among those a Carbon Border Adjustment Mechanism (CBAM). The CBAM aims to impose a carbon price on imported products whose production-related emissions have not been taxed (or not at the same level as in the EU) by the exporting country. The Committee of the European Parliament dedicated to environment adopted a resolution the 10th March 2021 validating the principle of a WTO-compatible European mechanism for border carbon emission adjustments. When this compensation mechanism was announced by the Commission, the United States was outside the Paris Agreement, its withdrawal had been initiated by the Trump Administration. But they have joined it again, with ambitious commitments in terms of abatements. Does the U.S. reversal give Europe hope to achieve its climate ambitions at a reasonable cost? We are not the first to quantify the economic and environmental efficiency of a compensation at the border. But different from the previous literature, we evaluate the proposal of the European Parliament with a dynamic general equilibrium model featuring imperfect competition, global value chains and GHG emissions. We show that the come-back of the US in the Paris agreement will have a much larger impact on global emissions, compared to the CBAM.

Key Words: Carbon Border Adjustment, International Trade, Climate Change.

JEL Codes: F14, F13, F17, Q56.

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Introduction

The new European Commission in office since December 2019 has announced that the EU will be climate neutral by 2050. A series of measures of the proposed *European Green Deal* will back this ambition, and among those a Carbon Border Adjustment Mechanism (CBAM afterwards) to be formally announced mid-July 2021.[1]

The CBAM comes as a complement to the central tool of the European Union's climate policy, the Emissions Trading Scheme (ETS). The ETS, set up in 2005, is a carbon market[2] that covers 40% of EU emissions generated by EU based firms of certain sectors during their production process. It presently sets a cap on these emissions so as to reduce them by 55% by 2030, with respect to 1990. The CBAM would add to this carbon market a carbon price on imported products whose production-related emissions have not been taxed (or not at the same level as in the EU) by the exporting country. The ENVI Committee of the European Parliament voted a first resolution in this sense on February 4, 2021, a vote in plenary session on the principle and the contours of a CBAM followed on 10 March 2021,[3] with a view to the presentation of the Commission's draft in June 2021. The text adopted takes into account a large number of recommendations made by legal and economic experts during the preparatory phase. The proposed mechanism is intended to be non-discriminatory, compatible with WTO rules (notably Articles I, II and exceptions under Article XX of the GATT) and signed free trade agreements. The members of the Parliament stress the environmental objective of the mechanism, while several stakeholder also seek to restore a level playing field among exporters worldwide.[4] The proposal for a regulation, to be formally announced by the Commission the 14th July 201 but leaked in June, should be in line with the proposal of the Parliament, with some differences such as the reference emissions used for compensation. The purpose of this regulation is to "[regulate] greenhouse gas emissions embedded in certain goods (...)

[1] "Should differences in levels of ambition worldwide persist, as the EU increases its climate ambition, the Commission will propose a carbon border adjustment mechanism, for selected sectors, to reduce the risk of carbon leakage. This would ensure that the price of imports reflect more accurately their carbon content. This measure will be designed to comply with World Trade Organization rules and other international obligations of the EU." *Communication from the Commission to the European Parliament, the European Council, the Council, the European economic and social committee and the Committee of the regions – The European Green Deal.*COM/2019/640 final, Brussels.

[2] The greenhouse gases covered by the ETS are: carbon dioxide (CO_2), nitrous oxide (N_2O) and perfluorocarbons (PFC). In the following, we loosely refer to this as carbon, hence "carbon market" and "carbon taxation". The overall emissions are measured in CO_2 equivalents, noted CO_2eq.

[3] The European Parliament resolution of 10 March 2021 *Towards a WTO-compatible European mechanism for border carbon emission adjustments* – procedure 2020/2043(INI) – was adopted with 444 votes for, 70 against and 181 abstentions.

[4] Art 7. of procedure 2020/2043(INI): "Supports the introduction of a CBAM, provided that it is compatible with WTO rules and EU free trade agreements (FTAs) by not being discriminatory or constituting a disguised restriction on international trade; considers that as such, a CBAM would create an incentive for European industries and EU trade partners to decarbonise their industries and therefore support both EU and global climate policies towards GHG neutrality in line with the Paris Agreement objectives; states unequivocally that a CBAM should be exclusively designed to advance climate objectives and not be misused as a tool to enhance protectionism, unjustifiable discrimination or restrictions (...). "

upon their importation into the customs territory of the Union, with the purpose of preventing carbon leakage." (Art. 1.1).

When the principle of such compensation mechanism was first announced by the Commission, the United States was outside the Paris Agreement (PA).[5] But it has just rejoined it again and the new US administration has announced new and ambitious targets in terms of abatement of emissions of GHG. Beyond the impact on global emissions, does this U.S. reversal give Europe hope to achieve its climate ambitions at a reasonable cost?

The European climate ambitions raise three issues: i) how to reduce direct and indirect international carbon leakages of its domestic climate policy (as acknowledged in art. 1.1 referred to above); ii) how to restore competitiveness of European producers (this objective is implicit in the regulation, but explicit in the preparatory report circulated by the Parliament and in the opening statement in the European parliament plenary session by Ursula von der Leyen, then candidate to the Presidency of the European Commission); and iii) how to encourage non-participating countries to join the effort to reduce emissions. Interestingly, on the latter issue, the European parliament is aware of the limits of the proposed mechanisms in terms of incentives: it "(...)encourages the Commission and the Member States to intensify their climate diplomacy ahead of and after the adoption of the legislative proposal for a CBAM and, in particular, to ensure continuous dialogue with trade partners in order to incentivise global climate action".'footnoteEuropean Parliament resolution of 10 March 2021, General Remarks 3.

Leakages and footprints are indeed tightly linked. The emitting European industries may displace part of their production in regions where the climate policy is less tight, while imports from non-taxing countries may partly substitute for European production (direct leakage). This jeopardizes European efforts since increasing imports of high carbon content products lead to a discrepancy between national inventories and carbon footprints. The fact that production techniques in less constrained countries are more carbon intensive could also add up and increase this leakage. Overall, as a result of the *direct* carbon leakage, the carbon content of European consumption would increasingly diverge from the carbon content of European production – hence the divergence between inventories on which Nationally Determined Contributions (NDCs) are based and carbon footprints. A second type of leakage (Felder & Rutherford 1993) can jeopardize the impact of EU efforts on the climate: the reduction for demand for fossil fuels in Europe will in turn depress prices of fossil fuels, leading indirectly to higher consumption by non-constrained

[5]The European Green Deal was officially announced on 11 December 2019. The Trump administration announced the withdrawal of the US from the Paris agreement on 1 July 2017 and enacted it on 4 November 2020.

countries, hence higher greenhouse gas (GHG) emissions. A compensatory taxation of carbon at the border of the EU would reduce the incentive to relocate in non-taxing jurisdictions and curb the divergence between inventories and footprint.[6] It would be helpless however regarding indirect leakages, or possibly counterproductive if it tends to increase the domestic carbon tax.

The second issue is about restoring the level playing field in carbon intensive sectors. European producers, who purchase emission allowances and invest in new technologies to abate their emissions, face higher costs and taxation than producers in third countries with laxer climate policies. As a consequence, they are at risk of loosing market shares in the export markets as well as on their own domestic market. It can be addressed by free allowances of emission quotas to energy intensive European industries (Böhringer, Carbone & Rutherford 2012) – the solution embraced by the EU till now – or through the envisaged CBAM possibly combined with tax rebates for the European exporters and temporary partial free allowances.[7]

Regarding the last issue – how to encourage non-participating countries to join the effort to reduce emissions – the CBAM is *de facto* ineffective for large countries that are not very open and therefore not very sensitive to the additional trade cost induced by the mechanism. The same for countries with which the EU has not a large bilateral trade. This is where the participation – or not – of the US to the Paris agreement makes a big difference. A European CBAM would hardly curb indirect leakages in a large and relatively closed economy such as the US, and would hardly be an incentive to embark into carbon taxation. In contrast, the presence of the US in the Paris agreement fixes this incentive problem as far as the US are concerned. By rejoining Paris, the new US administration is a bit of a game changer.

This paper aims at putting numbers on these issues. While the mechanisms underlying the impacts of an unilateral environmental policy are well known (Felder & Rutherford 1993), their relative magnitude and therefore the size of the resulting leakages remains an empirical question, depending on the characteristics of the policies in place, of the implementing countries and the affected sectors. Our contribution to the literature is to evaluate the proposal of the European Parliament and compare its outcome to what the come-back of the US in the Paris agreement changes in terms of impact on emissions. Our modelling features a reference path for the world

[6]This problem has been identified for a long time: Markusen (1975) suggested a simple solution consisting in capping national emissions by a tax and introducing a tariff at the border.

[7]Combining a cap-and-trade system with a tax at the border and a rebate on exports very much resembles a consumption tax (Elliott, Foster, Kortum, Munson, Perez Cervantes & Weisbach 2010). There is actually equivalence if and only if i.) the CCBA taxes carbon at the exact same price as the domestic tax; ii.) the carbon tax is fully passed onto the consumer by producers and iii.) there is full rebate for exporters. Then domestic producers and foreign producers pay the carbon tax when selling their products to domestic consumers, while no producer (domestic or foreign) pays the tax when serving foreign consumers.

economy; it links trade and GHG emissions taking stock of Global Value Chains, imperfect competition and substitution among energies and among capital and energy. Such Dynamic Computable General Equilibrium (CGE) modelling encompassing international trade and emissions is particularly adapted to address the economic impact of climate-change mitigation policies and the level of ambition required to reach the commitments. Calibrated multi-sectoral and global dynamic general equilibrium models allow to trace production displacements across sectors and regions and, as a consequence, account for carbon leakages. Relying on a model taking explicitly into account Global Value Chains is also important when emissions related to intermediate consumptions have to be embarked. Based on such modelling, we ask whether a European CBAM can efficiently curb global emissions in a context where not all countries adopt a cooperative behavior.

First, we consider the trajectory of the world economy in terms of GDP and induced emissions in absence of any abatement policy. Then, we take stock of the targets announced by countries as a follow up of the Paris agreement, based on their *unconditional* NDCs. To proceed we use the last series of unconditional NDCs as of April 22, 2021 (USA, UK, Japan and Canada announced new NDCs, complementing the announcements of the European commission). This second step constitutes our baseline: a world growing till 2040 where countries abate their emissions according to their NDCs. Then, we implement a CBAM at the border of the EU, i.e. an import tax based on the emission intensity of the domestic country (hence of the EU, not the emission intensity of the exporter). Such choice of reference emissions would have less hold on foreign emissions and leakages, but would arguably preserve consistency with international obligations of the EU (it would be more difficult for affected countries to raise a case at the WTO). Alternatively, we explore the consequences of considering emissions of the exporter as a reference.

In a first experiment, only industries covered by the European scheme of emission quotas are covered by the CBAM, and we take on board the direct emissions associated with the use of energy in these industries. Indirect emissions induced by the the energy mix of electricity used in the production are not taxed. The indirect GHG emissions implied by other intermediate consumptions are not considered either, in order to take into consideration the practical feasibility of the taxation. This first combination of assumptions is more restrictive than the short term target envisaged by the European Parliament, which suggests to extend taxation to the indirect emissions of the energy used. Free allowances are no longer distributed in the EU.[8]

[8]Free allowances are contentious: lobbying of emitting industries led to keep the option of phasing out progressively these allowances? The CBAM would then only be applied to the fraction of allowances that is purchased on the ETS market. In contrast, the leaked proposal of the Commission states that "the Mechanism is an alternative to (...) the allocation of allowances free of charge (...)" (Art. 1.3). We will endorse in the following this approach which is consistent with WTO rules.

In a second experiment, we add a rebate of allowances purchased on the ETS market to European exporters. We rebate only half of the acquired allowances.[9]

In a third experiment, we exclude for the mechanism low income exporters in line with the usual Special and Differential Treatment principle at the WTO, and with the recommendation of the European Parliament.[10]

Lastly, we compare the outcome of the CBAM with the return of the US in the Paris agreement. We rely on the updated NDCs of the US as of April 22, 2021.

To proceed, we use the MIRAGE-VA model, developed at CEPII (Bellora & Fouré 2019). It is a global, dynamic, multi-sectoral and multi-regional model, featuring imperfect competition and a detailed representation of energy use. In particular, as it is standard in energy-oriented models, energy is not considered as an intermediate consumption but directly substitutes with capital in the production function. In addition, energy is subject to independent productivity improvements, specifically calibrated. GHG emissions due to both energy use (carbon dioxyde) and production processes (carbon dioxyde, methane, nitrous oxyde and fluorinated gases) are explicitly reported. The model also accounts for trade policies, based on highly disaggregated databases of the *ad valorem* equivalents of tariff and non tariff protection, as well as climate policies, in particular cap and trade mechanisms. The model additionally embeds an improved representation of value chains that, coupled to the results on emissions, allows to discuss in details the impacts on GHG leakage through international trade and on GHG footprints.

We are not the first to quantify the economic and environmental efficiency of a compensation at the border. Elliott et al. (2010) perform a quantitative analysis of scenarios of compensating carbon taxes at the border of Annex B countries (before the US opt out) using a CGE.[11] Babiker & Rutherford (2005) quantify with a CGE the effectiveness and consequences of various CBA schemes (Voluntary Export Restraints, compensating tariff, free allowances, export rebates) under the Kyoto protocol after the US opt-out. Using a static and partial equilibrium model of the main sectors covered by the EU ETS, Monjon & Quirion (2011) compare the impacts of border

[9]Rebates are weakly supported by the European Parliament and would hardly be WTO consistent. Specifically, any tax rebate would provide a competitive advantage to European producers exporting to markets taxing carbon domestically without imposing a CBAM. Accordingly, a full tax rebate could easily be challenged at the WTO as long as not all importers impose a CBAM, and we adopt this conservative approach of rebating only half of the allowances.

[10]Art. 8 of (2020/2043(INI)): "Least Developed Countries and Small Island Developing States should be given special treatment in order to take account of their specificities and the potential negative impacts of the CBAM on their development".

[11]We refer here to Annex B of the Kyoto protocol. This Annex sets binding emission reduction targets for 36 industrialized countries and the European Union, over the period 2008-2012. The countries *not* listed in the Annex B have no binding commitment, under the principle of the "common but differentiated responsibility and respective capabilities".

adjustments and output-based allocation (free allowances) and conclude that border adjustment is preferable. Böhringer, Bye, Fæhn & Rosendahl (2012) consider alternative designs for compensating *tariffs*, and analyze their effects on global welfare within a multi-region CGE model of the global economy. The carbon content for compensation at the border includes indirect emissions associated with intermediate non-fossil inputs corresponding to indirect carbon from electricity use and indirect carbon from non-electric and non-fossil intermediate inputs. The tax rate is either based on the average of the coalition or on the average of opting-out countries or alternatively on the actual emissions of the exporting country. The abatement of carbon emissions is obtained through exogenous emission constraints or CO_2-taxes. Compensation is applied alternatively on EITE sectors only or on all sectors. Weitzel, Hübler & Peterson (2012) and Antimiani, Costantini, Martini, Salvatici & Tommasino (2013) examine the consequences of a CCBA modelled as a tax compensating for internal carbon prices at the borders of a coalition comprising Europe, USA and other Annex I countries.[12] Manders & Veenendaal (2008) quantify with a CGE the outcomes of two scenarios (ETS imposed in Europe only versus coalition with other Annex I countries, plus Brazil, India and China) combined with different instruments: tax levied on the carbon content of EITE imports; export refund; redistribution of auctioning receipts to emitting sectors; Clean development Mechanisms with the EU investing in clean technologies in the developing world (as an alternative to more expensive emission reductions in their own countries). Kuik & Hofkes (2010) use a CGE to quantify the impact of two CBA-type policies in presence of the European ETS: obligation of purchasing allowances for importers of EITE products based on reference direct emissions in the EU versus in the exporting country. The model abstracts from any other cap-and-trade system. Böhringer, Carbone & Rutherford (2012) assess three proposals for leakage reduction with a CGE: CBA, industry exemptions, and output-based free allowances. The coalition comprises either Europe only, or Annex I countries, or the latter countries plus China. The CBA is implemented as tariffs levied on the carbon content (direct emissions plus indirect emission from electricity use) of imported EITE products. Böhringer, Garcia-Muros, Cazcarro & Arto (2017) performs the same type of analysis but focused on the US initial NDCs under the Paris agreement. McKibbin, Morris, Wilcoxen & Liu (2018) rely on a CGE to quantify the economic and environmental impact of a taxation of carbon in the US in presence of a CBA. Böhringer, Carbone & Rutherford (2018) rely on a CGE to quantify the consequences of compensating carbon at the borders of OECD, with OECD applying a taxation of its emissions and possibly compensating non-OECD with lump-sum transfers. Fouré, Guimbard & Monjon (2016) take a slighlty different

[12]We refer here to Countries that are listed in Annex I to the UN Framework Convention on Climate Change.

perspective and explore the impacts of a CBAM in the presence of retaliatory measures that trade partners could take if considering the mechanism as not compliant with WTO rules. Böhringer, Schneider & Asane-Otoo (2021) assess the impact of carbon tariffs by combining WIOD data with a static CGE. They show a sharp increase in emissions embodied in OECD countries' imports from developing economies. While this pattern reinforces the impact of carbon taxation at the border (with a 64-80% leakage reduction due to carbon tariffs depending on scenarios), it somehow shifts the burden of adjustment to developing countries. Importantly, they show that a growing share of those imported emissions stems from electricity production which provides guidance in terms of design of the CBAM as the electricity mix is very sensitive to the indirect leakage channel.

We contribute to this literature in three ways. First, we carefully model the policy options envisaged by the European parliament, sticking to a version which sounds like WTO-compatible. Second, we rely on a dynamic baseline of the world economy accounting for unconditional NDCs associated with the Paris agreement, including the withdrawal and the return of the US. Third we use a model taking stock of the intermediate versus final nature of traded goods, which helps tracking the consequences of various approaches to the CBAM along the value chains.

1 Setting the stage

The tension between ambitious commitments to reduce global GHG emissions and the maintenance of the open multilateral trading system is becoming a major political issue. Governments have to make GHG taxation acceptable to their constituents and bearable by their companies in the absence of international coordination. In the long term, the benefits of GHG reduction are immense for each country, but none of them has an individual incentive to act in the right direction, which is another an illustration of the "tragedy of the commons" (Gollier & Tirole 2015). The climate is an international public good, the preservation of which would justify, in the first analysis, the establishment of a policy at the global level. However, there are three main obstacles to this solution. First, developing countries are now affected by the climate consequences of the past industrialization of advanced economies; requiring them to implement costly policies that could impede their growth poses a problem of intertemporal redistribution of income at the global level. Second, countries not participating in the effort to reduce GHG emissions benefit doubly from the efforts of countries making the opposite choice: they benefit from less climate degradation, while paying less for their carbon energy due to lower global demand. Finally, non-participating countries become attractive locations for activities with high GHG emissions (pollution haven hypothesis), which distorts international competition and encourages relocation.

1.1 From the ETS to the CBAM

The central tool of European policy today is the European Union Emissions Trading Scheme (ETS). This market concerns the Member States and a few other countries.[13] The United Kingdom left the scheme during the Brexit. The emissions of more than 10,000 industrial emitters are covered (steel industry, cement plants, fossil fuel power generation, domestic airlines in the European area). In total, 40% of European emissions are covered.[14] This market is referred to as a cap-and-trade market. A cap on emissions is set, which decreases over time to reach the EU target; industrial companies trade emission permits on the market thus constituted in proportion to their emitting activity.

Unfortunately, a local policy such as the European one will hardly solve a global problem: the EU represents less than 10% of global emissions (3.6 Gt CO2eq in 2020) and the inaction of non-participating countries reduces the effectiveness of European policies. Carbon leakages result from the displacement across regions of production, as well as from the displacement of demand, both for taxed goods and for energy, according to their relative prices. International coordination on GHG emissions reduction is therefore essential. Several approaches are therefore possible: i) a flexible plurilateral agreement in which the various signatory countries announce emission reduction targets compatible with their level of development – this is the principle adopted for the Paris Agreement; ii) a taxation mechanism aimed at neutralizing the environmental and economic impact of the differences in carbon prices in the various countries - this is the CBAM; finally iii) a Climate Club bringing together countries with high ambitions and sanctioning in an undifferentiated way all imports from non-member countries (Nordhaus 2015). The first two solutions are not exclusive and there may be advantages in combining them. This is the direction proposed by the European Commission.

Even with such a combination of tools, a key factor for success is the participation of high emitting countries: this increases the climate impact of the policy, reduces the collective cost of free-riding behaviour and avoids a high level of taxation for a high emitting country with strong trade retaliation power. By announcing, in the absence of the United States in the Paris Agreement, the upward revision of its climate ambition, the EU has therefore taken a risk. While this strategy has proven successful with the change of US administration, the devil will be in the details regarding

[13]Norway (the ETS represents only a small part of the taxation of this country), Liechtenstein and Iceland.
[14]Remaining emissions must be curbed using other mechanisms.

the implementation of the CBAM.

1.2 The European parliament choices

The practical implementation issues concern i) the industrial scope covered; ii) the tax base (i.e. reference emissions); iii) the tax vehicle (customs duty, tax, emission allowance purchased by the EU importer); iv) the allocation of revenues (general European budget, revenue allocated to decarbonization, international transfer); v) the possible return to European exporters of the rights acquired on the ETS; vi) the maintenance or termination of the free allocation of allowances to the industries of the ETS; and finally, vii) the possible special and differential treatment of the imports from Least Developed Countries (LDCs).

What scope? The European Parliament draft proposes two stages: firstly, industries covered by the ETS, and secondly, all products, according to their indirect content in products covered by the ETS, in order to avoid a toll on the competitiveness of downstream European industries.[15]

Which base? To ensure the effectiveness of the CBAM, it would be appropriate to use the actual emissions of the exporting country, which it has no interest in revealing if they are higher than those of the EU. Thus, how to know the carbon content of imported products? It is in the exporting country's interest to reveal this content only if it is lower than the content of equivalent European products (thus avoiding the tax), which should not happen in countries where carbon is not taxed, since the production units there are less efficient. There are two possible solutions: to apply a carbon "package" for comparable products and comparable countries, or to consider the European carbon content and apply it to imported products. Using the "package" approach, the EU runs the risk of a dispute before the Dispute Settlement Body (DSB) of the World Trade Organization (WTO) because the measure would introduce significant differences in taxation between exporting countries. This is anyway the solution envisaged by the European Parliament, with reference to average global emissions.[16] The alternative solution, the average EU content, would secure WTO-compatibility, but only part of the carbon content of imports would be covered, such that the CBAM would compensate only *partially* the competitive differential for European producers.

Which vehicle? How to financially compensate for the difference in carbon content between European and imported products? A first solution is to impose a customs duty calibrated to this

[15] "Art. 12 of (2020/2043(INI)): In order to prevent possible distortions in the internal market and along the value chain, a CBAM should cover all imports of products and commodities covered by the EU ETS, including when embedded in intermediate or final products; (...) as a starting point (already by 2023) and following an impact assessment, the CBAM should cover the power sector and energy-intensive industrial sectors like cement, steel, aluminium, oil refinery, paper, glass, chemicals and fertilisers (...)".

[16] Art. 13 of (2020/2043(INI): If data is not made available by the importer, account should be taken of the global average GHG emissions content of individual products.

difference. Here again, the prospect of difficulties at the WTO arises: this customs duty would be discriminatory (not all exporters would pay the same customs duty), which may contravene one of the founding principles of the WTO, not to say that the duty would vary daily like the price of carbon. A second solution is to impose a tax at the border. The difficulty is then not in Geneva but in Brussels, because taxation issues are decided unanimously by the member countries. Faced with these difficulties, one might prefer to ask European importers to acquire carbon permits on the ETS market, in the same way as producers located in the EU. However, it would be necessary to modify the fundamental parameters of the ETS, i.e. the supply of permits and the emission cap, in order to reintegrate the substantial "imported" European emissions into the market. The European Parliament favors the purchase of emission allowances by European importers (without excluding the principle of a tax, but which would require a unanimous vote in the Council, as it is a fiscal measure). But, very cleverly, to avoid unbalancing the ETS, the Parliament proposes the creation of a *second* market, reserved for importers, on which the price is set by the first market. If the price is fixed, then the quantities of allowances on the second market should be adjusted.[17]

What allocation of revenues? Finding a satisfactory answer (from the point of view of WTO rules) to the question of the use of the revenues is an important point. The terms of the WTO environmental exception on which the European CBAM could be based would not necessarily allow the revenues generated by the CBA to be used to fund the European budget indiscriminately, contrary to what has been suggested in the Commission's first communications. At the very least, these funds should be directed towards financing decarbonization projects in the EU. Their use to finance decarbonation in developing countries would indeed be preferable, although more challenging from a political economy perspective: these countries use less efficient techniques and therefore the gain in terms of decarbonation of a euro invested is greater; and these countries do not necessarily have the financial means to make these investments, so there would be no windfall effect. The text adopted by the European Parliament insists on the need to have resources earmarked for decarbonation in the EU or in the LDCs, and not to increase European resources without precise allocation.[18]

What restitution? Rebating to exporters the cost of the permits they had to acquire on the ETS market is an option. Combining border compensation for imports and refunds to exporters is very

[17] Art. 16 of (2020/2043(INI): "importers should buy allowances from a separate pool of allowances to the EU ETS whose carbon price corresponds to that of the day of the transaction in the EU ETS".

[18] Art. 16 of (2020/2043(INI): "asks the Commission to ensure full transparency about the use of those revenues; (...) those new revenues should allow for greater support for climate action and the objectives of the Green Deal, such as the just transition and the decarbonisation of Europe's economy, and for an increase in the EU's contribution to international climate finance in favour of Least Developed Countries and Small Island Developing States, which are most vulnerable to climate change.

similar, from the point of view of economic analysis, to a consumption tax, without the problems of acceptability that this would raise.[19] However, rebating has an undesirable consequence: European exporters would no longer have an incentive to reduce their emissions, or a lesser incentive if they also sell on the European market, which is still subject to obtaining permits. The wording of the text adopted by the Parliament remains ambiguous but reflects limited support for the idea of a refund to European exporters that could be interpreted as an export subsidy for carbon products.[20] In the absence of a refund to exporters, CBAM cannot therefore be considered equivalent to a consumption tax.

Finally, a *modus operandi* is emerging: the objective should be, in a first phase, to tax imported products covered by the ETS on their direct and indirect carbon content, as revealed by European producers, to the extent of the difference in carbon prices in the exporting country (at the end of the value chain) and in the European Union. In a second phase, this would be extended to all products based on the carbon content of their intermediate consumptions. In both cases, importers would have to buy allowances on a second market, at the price of the existing ETS, covering the difference between the price of carbon in the EU and the price of carbon in the exporting country.[21]

2 Our modelling assumptions

Our approach combines three tools: (i) a global and sectoral general equilibrium model featuring recursive dynamics and emissions of GHGs; (ii) a dynamic baseline of the world economy up to 2040 and (iii) a rich set of data to implement detailed trade and climate policies. We present sequentially these three elements.

2.1 The General Equilibrium model

MIRAGE-VA is the multi-sector and multi-region computable general equilibrium model developed at the CEPII to assess the impact of trade policies and the interactions between trade and climate

[19] A MACF combined with a refund is generally considered equivalent to a consumption tax if it taxes carbon at exactly the same price as the domestic tax; if the carbon tax is fully passed on to the consumer by producers; and if exporters receive a full refund. Thus, European producers and their foreign third-country competitors pay the carbon tax when selling to European consumers, while no producer (European or not) pays the tax when serving third-country consumers.

[20] Art. 29 of (2020/2043(INI)): "urges the Commission, therefore, to consider the possible introduction of export rebates, but only if it can fully demonstrate their positive impact on climate and their compatibility with WTO rules; stresses that (..) any form of potential export support should be transparent, proportionate and not lead to any kind of competitive advantages for EU exporting industries in third countries".

[21] Garicano (2021) details the choices of the Parliament and explains the envisaged gradual phasing-out of free allowances.

change. It innovates by featuring GVCs and an improved representation of GHG emissions.[22]

In the model, firms interact either in a monopolistic competition (a number of identical firms in each sector and region compete one with another and charge a markup over marginal costs) or in a perfect competition framework (a representative firm by sector and region charges the marginal cost), depending on the sector that is considered. Production combines value-added plus energy and intermediate consumption, while demanding five primary factors (labor with two different skill levels, capital, land, natural resources), fully employed.

In each region, a representative consumer gathers households and the government. It maximizes its utility under its budget constraint. This representative agent saves a part of her income and spends the rest on commodities, according to a LES-CES functional form.

Trade is represented with two different Armington structures, one for final consumption and one for trade in intermediates. This double structure explicitly accounts for GVCs. In both structures, domestic and imported goods are imperfectly substitutable, as are imported goods from different origins.[23] What the double Armington structure indeed captures is the difference in the preferences in the base year for a given sector (e.g. Vehicles) since, for instance, the share of imports coming from a given country is not the same whether they are of final (e.g. cars) or intermediate goods (e.g. components). Furthermore, it allows to apply policy shocks differentiated by the use of goods. Trade can be impacted by a wide range of measures, systematically differentiated according to the use of the affected goods. We explicitly consider tariffs and export taxes. Trade restrictiveness of non-tariff measures (NTMs), both on goods and on services, is also taken into account, under three possible different forms: tariff equivalents, export tax equivalents and iceberg costs. Section 2.3 provides details on data sources for each of this measures. International transportation is explicitly modelled: transportation demand is *ad volumen*, it can be satisfied through different transport modes, supplied by different countries.

Finally, MIRAGE-VA is a recursive dynamic model: agents optimize their choices intra-temporally and the model is solved each year until the last year considered in the simulation. A putty-clay formulation captures the rigidity in capital reallocation across periods: the stock of capital is immobile, while investments are allocated each year across sectors according to relative

[22]MIRAGE-VA is the extension of MIRAGE-e documented in Fontagné, Fouré & Ramos (2013) that did not differentiate the demand of goods according to their use, whether for final or intermediate consumption, and that did not considered GHGs other than carbon dioxyde. More information on the version used here is available on the MIRAGE wiki: https://wiki.mirage-model.eu. MIRAGE stands for Modelling International Relationships in Applied General Equilibrium.

[23]Elasticities of substitution across origins do not differ according to the use of goods, meaning that we actually assume that the behavior of an importer is the same whatever the kind of good (for final or intermediate use). These elasticities were estimated by Hertel, Hummels, Ivanic & Keeney (2007). They are higher than the elasticity of substitution between domestic and foreign goods.

return rates. In other words, structural adjustments result from the inertial reallocation of the stock of capital via depreciation and investment. The baseline required for dynamic simulations is calibrated in close relationship with the MaGE model and the resulting EconMap database (Fouré, Bénassy-Quéré & Fontagné 2013) to deal with world structural change at medium-run horizon (2040).

The model is calibrated using the ImpactECON database (Walmsley & Minor 2016) featuring a decomposition of trade in goods and services by final or intermediate use that is consistent with GTAP 9.[24] This release of the GTAP database features 2011 as the last reference year. The geographic decomposition is 140 regions of the world economy for 57 sectors. We aggregate this data into 23 sectors and 23 regions or countries (see Table A1 in the Appendix for the detailed aggregation).

2.2 GHG emissions and related data

To account for GHGs emissions, MIRAGE-e explicitly considers the consumption of five energy goods (electricity, coal, oil, gas, refined petroleum). In firms' consumption, the bundle of these five goods substitutes with capital, in the value added structure, instead of substituting with intermediate consumptions. Within the energy bundle, oil, gas and refined petroleum are more substitutable than coal or electricity (see Appendix A.1). To avoid unrealistic results, energy production sectors other than electricity deserve a special structure: a constant Leontief technology is assumed, to avoid, for instance, to produce refined petroleum from gas and electricity. Improvement in energy efficiency is embedded, at the level of the capital-energy bundle, its growth follows the growth rate of the energy productivity projected by the Mage model (see below, section 2.4).

Endogenous technical progress is also present in the model. It is implicit, as producers can substitute capital for energy when they renew their capital stock, according to a nested CES production function. Given the depletion rate used in MIRAGE, this leaves the possibility of renewing 90% of the installed equipments at the 2040 horizon considered here. This mechanism, which mimics an technical progress induced by the increase in the carbon price, limits endogenously

[24]The "ImpactECON Global Supply Chain package" allows converting the GTAP 9.0 data into a global supply chain database. Since the goods traded in GTAP are aggregated within sectors over numerous HS-6 products categories, a given resulting sector can provide the same category of good to final consumer and to other sectors that use it as an intermediate product. Tariffs differ by HS6 category and thus by main use of the output of the sectors, as well as by the source and destination of the good. Combining COMTRADE and the Broad Economic Categories of the UN, ImpactECON fixes this problem: each bilateral flow in a GTAP sector is split into final and intermediate use. The GTAP 9.0 database is thus converted into a "Global Supply Chain Database", a database of value of imports of commodities purchased by sectors (intermediate), households (final), government and investment (final), by source and destination country/region, at market, agent and world prices. Notice that although the database also provides the tariffs aggregated along the same dimensions, we do not rely on the latter as we proceed with our own aggregation of the MAcMap HS6 database.

the increase in this latter price.

Carbon dioxyde emissions are proportional to the consumption of the energy goods corresponding to fossil energy (coal, oil, gas, refined petroleum), based on fixed parameters determined in the initial year. They arise from the intermediate consumption (use in manufacture production processes) as well as the final consumption (e.g. domestic heating fuel) of fossil fuels.

GHGs other than carbon dioxyde, namely nitrous oxyde, methane and fluorinated gases are considered as emitted during the production process. More precisely, these three GHGs are treated as production factors within the production functions. Their position in the production function, i.e. their relative substitutability with respect to other factors and intermediate consumptions, varies across sectors, following Hyman, Reilly, Babiker, De Masin & Jacoby (2003). Their substitution elasticity is taken from the literature.

The climate policy instrument present in our framework is a tax on GHG emissions, which can be GHG-sector-region and time specific. The level of the tax is either exogenously imposed to the model or endogenously computed to fulfill a target imposed on GHG emissions, mimicking a cap-and-trade carbon market, such as the European Trading Scheme. This cap-and-trade setup is used to implement the commitments taken in the Paris Agreement by its signatories. More precisely, we consider all the *unconditional* commitments, and disregard conditional ones, as reported in the National Determined Contribution interim registry of the United Nations Framework Convention on Climate Change (UNFCC). Following the Washington Summit held on 22 April 2021, we updated the commitments of Canada, Japan, the United Kingdom and the US, even if not all these new pledges led to an update of the registry at the time of the simulations.[25] We translate all the considered commitments, whether formulated in absolute or in intensity terms or formulated with respect to a business as usual reference, in a relative reduction with respect to 2011, the base year in our simulations. We then apply this reduction linearly from 2011 to the horizon retained in NDCs. If this horizon occurs before 2040, which is the case for the majority of the commitments considered, we keep the commitment unchanged until 2040. Technically speaking, the commitments translate in a yearly cap on GHG emissions, imposed to each committed region of our regional aggregation, and the model then endogenously adjusts the level of a tax on GHGs to meet this target.[26] In other words, we consider here that all the countries fulfill their commitments

[25]The EU officially published its commitment to reduce its GHG emissions by 50% in 2030 with respect to 1990 in the UN registry update made in December 2020.

[26]By construction, the GHG cap is *always* reached in our setup, it is not possible to be more virtuous than planned in the NDCs. Unless differently specified, the carbon tax covers all the emissions, included those due to the burning of fossil fuels by final consumers, with the exception of the emissions caused by the transportation of international freight, which are excluded from the Paris agreement.

based on a cap-and-trade system, while they are actually free to choose the policy instruments they prefer.

Lastly as far ar the implementation of climate policies is concerned, the EU carbon market deserves a special consideration. The EU put in place the *European Trading Scheme* in 2005. In order to reach the target of -55% of economy-wide emissions by 2030 set in the EU new NDCs, we consider two carbon taxes in the EU: one specific to the ETS, and one that applies to all other sectors and to final consumers. The level of this second tax is set to achieve the Paris target, conditional on the reductions undertaken in the ETS sectors.

Unless otherwise specified, emission data are taken from the GTAP-E database and the satellite data on non-CO_2 emissions provided by GTAP.

2.3 Protection data

Market Access Map (MAcMap) provides a disaggregated, exhaustive and bilateral measurement of applied tariff duties at the product or tariff line level. It takes regional agreements and trade preferences exhaustively into account. The raw source data is from ITC (UNCTAD-WTO). The HS6 data set used here was constructed by the CEPII (Guimbard, Jean, Mimouni & Pichot 2012) for analytical purposes and provides an *ad valorem* equivalent (percentage) of applied protection for each triplet importer-exporter-product. To minimize endogeneity problems (when computing unit values or when aggregating data), it relies on "reference groups" of countries: bilateral unit values and bilateral trade are replaced by those of the reference group of countries in the weighting scheme (Bouet, Decreux, Fontagné, Jean & Laborde 2008). MAcMap-HS6 treats specific duties (per unit) as well as TRQs and offers MFN for all WTO members. The last two years reported in MAcMap are 2011 and 2013, both considered in the following exercise. *Ad valorem* equivalents of NTMs affecting goods are taken from Kee, Nicita & Olarreaga (2008), they are split across import taxes, export taxes and iceberg costs in an equally proportional way. *Ad valorem* equivalents of NTMs applying to services are from Fontagné, Mitaritonna & Signoret (2016) and are taken into account in the form of iceberg trade costs.

2.4 The dynamic baseline

The effects of the EU CBAM are measured in terms of deviation from a dynamic baseline, using a 15 years horizon in order to fully capture the dynamic adjustments of the economies. The baseline is build in two steps. First, it relies on a macroeconomic model of the world economy, MaGE, used in projection up to 2035 (Fouré et al. 2013). This three-factor model (labor, capital and energy) details the working population by education level, age group and gender. It represents a dual process of international convergence of technological levels and energy efficiency. It includes a life cycle determining the level of savings according to the demographic pyramid, a Feldstein-Horioka mechanism determining the international mobility of capital and a Balassa-Samuelson real exchange rate appreciation mechanism. It consistently projects, for each country, the GDP, the savings rate, the current account, and the energy efficiency.

The MIRAGE model uses the same exogenous variables as MaGE, as well as the current account targets, the investment rate and the GDP trajectories provided by MaGE for each country in a first simulation (step 1 of the reference) that reconciles the two models (given the chosen aggregation of countries in regions). The endogenous variable is the TFP in the manufacturing sector conditional on the agricultural TFP (exogenous) and on a constant difference in TFP between manufacturing and services. This first reference trajectory of the world economy is accordingly defined in absence of any commitment in terms of abatement of GHG emissions.

The next step consists in constraining this reference trajectory to be consistent with unconditional commitments of countries or regions of the word economy. In this second step we also update the tariff protection to its level of 2013 (the most recent available in the MAcMap-HS6 database)[27] and represent – in a stylized way – the most recently signed or negotiated trade agreements: the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP), the EU-Japan Economic Partnership Agreement, the Comprehensive Economic and Trade Agreement between the EU and Canada and a soft Brexit.[28] For all the new trade agreements, we remove all the tariffs but leave the NTMs unchanged. In the second step of the baseline, the GDP becomes endogenous and the emissions caps are binding while the price of carbon adjusts in each country in that step.[29].

To sum up, the general equilibrium model is first run to calibrate the TFPs; a second run, updating trade protection, then constitutes what we consider our baseline. We then build policy scenarios, in which we implement the policies we are interested in. The only element that differs between the baseline and a policy scenario is the policy of interest. Then, comparing the economic outcomes of the policy scenario to those of the baseline allows to assess the impact of the trade

[27] We do not consider changes in the MFN rates following 2013. In particular, the decreases in MFN tariffs implemented by China in 2018 and 2019 are neither taken into account in the baseline nor in the policy scenarios.

[28] We represent a soft Brexit by leaving the tariffs applied by the UK and the EU unchanged, while increasing their bilateral NTMs to halve the preferential access of the UK to the EU market, and reciprocally.

[29] This treatment indeed introduces a constraint in terms of geographic aggregation of the model: regions of the world economy must be consistent in terms of their NDCs. The existing aggregation in GTAP imposes slight departures from this consistency for certain "Rest of" regions. We also aggregated a couple of small size economies to larger groups for computational purposes.

policy implemented in the scenario.

3 Results

Table 1 details the macroeconomic impact of our three scenarios on the European economy. The baseline is the world economy in 2040, with all countries with unconditional NDCs capping their emissions according to those NDCs, including the US. The first column is showing the impact of the introduction in 2023 of the CBAM with no rebate to exporters and no special and differential treatment for LDCs. The second column adds the rebate (50% of the purchased allowances) to EU exporters of ETS products, with no SDT. The third column adds the SDT to the first column, in absence of restitutions. All figures are in percentage deviation from the baseline in 2040, at constant prices.

The CBAM with no restitution has a significant negative impact on the GDP of the EU. The 0.77 percentage point drop in the EU GDP was probably not expected by supporters of the measure and deserves a detailed explanation. The purpose of the distortion introduced by the CBAM (one additional tax) is to correct another distortion (of competition). In such second best situation, the outcome may be positive or negative. Interestingly, column 1 shows that not only imports (of intermediate and final goods) are reduced, but exports also.

As for final goods exports, this is the outcome of a toll on the competitiveness of downstream industries clients of ETS producers. With the adjustment at the border, downstream industries will purchase their intermediate consumptions at a higher price, either because they import these inputs now subject to the compensation, or because they purchase European inputs also at a higher price. As a result, they loose market shares both on the European and foreign markets. The drop in final goods imports is the outcome of the general equilibrium effect of a lower GDP.

Intermediate good producers find it more profitable to sell their products on the European market given the restriction on competing imports. By the same token, they become less competitive because the price of carbon in the EU increases. Their accordingly reorient their sales towards their domestic market at the expense of their exports.

It is worth emphasizing why European inputs see their price increasing. As EU ETS producers have to purchase allowances in order to respond to the additional demand substituting European inputs to imported inputs, they increase the demand for allowances, the latter being caped to respect the targets of the NDCs. Thus, the carbon price increases on the first ETS market by 25.7%, although importers purchase allowances on a second market as envisaged by the European parliament. A simpler interpretation tells us that ETS products are homogenous: a tax at the border accordingly inflates indifferently the price of imported and domestic affected products.

We have to gauge the efficiency of the instrument with regard to its objective which is to reduce the leakage induced by the European ambition in terms of abatement, and more generally to reduce global GHG emissions. We are going to detail this point later but it is important to notice that the CBAM has no impact on EU emissions of GHG because we hypothesize that the cap in terms of emissions is binding in the reference situation, as well as in the counterfactual scenarios. The only impact that it may have within the EU is to redistribute this cap between firms subject to the ETS, on the one hand, and the rest of the economy, on the other hand. But what is really striking is the impact of the CBA on the price of carbon permits in the ETS market: the 25.7 % increase is induced by the higher demand of permits by high-emitting industries because they are protected from foreign competition by the CBAM. Recall that the supply of permits is fixed so as to fulfill the commitments taken under the Paris Agreement.

These results can be contrasted with the impact of a CBAM combined with a rebate to exporters of goods covered by the ETS. Column 2 of Table 1 shows the latter results. Now, the toll on European exports of intermediate goods is amortized because of this implicit subsidy to exports of emitting industries. Last, the increase in the price of carbon on the ETS market is magnified by this policy encouraging emitting industries to increase their output, and giving them a negative incentive in terms of energy efficiency. This additional increase in the cost of carbon allowances further reduces the competitiveness loss of EU exporters of final products. They also suffer an additional loss of competitiveness on their internal market, which limits the drop in imports of final goods.

Lastly, if LDCs are exempted of CBAM, the impact of the policy on the European economy is alleviated, as expected. We will discuss below whether the efficiency of the CBAM in terms of curbing emissions is also reduced.

We now look at the sectoral results. Let's start without rebate in Figure 1. The impact of changes in domestic demand (which is reduced by the higher price of carbon in domestic products, directly or indirectly through the price of intermediate consumption), combined with the change in exports (negatively affected by the higher cost of carbon intensive intermediate consumption) and imports (negatively affected by the CBAM in ETS sectors, but positively affected by the loss of competitiveness of downstream sectors in the EU), subsumes in variations in the sectoral value added. Other mechanisms to look at are the outcome of the substitution between energies

Table 1: Impact of the CBAM for the EU (*based on the average emitting intensity of European producers*)

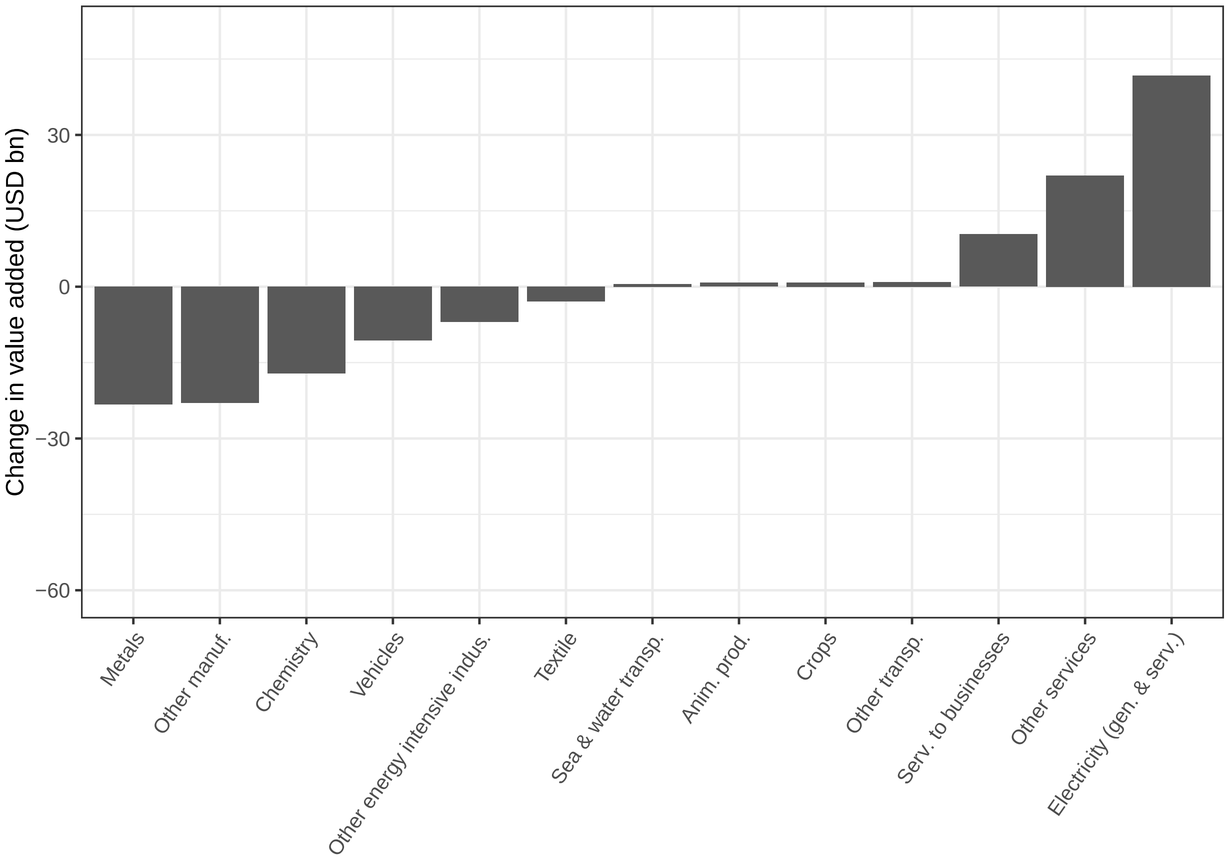
	CBAM	CBAM + rebate	CBAM + SDT
GDP	−0.77	−0.87	−0.63
Exports			
Exports of intermediate goods	−4.53	−2.48	−3.57
Exports of final goods	−3.24	−4.27	−2.65
Imports			
Imports of intermediate goods	−3.97	−3.50	−3.00
Imports of final goods	−2.03	−1.29	−1.60
ETS carbon price	25.70	32.87	22.10

Notes: percentage difference in 2040 with respect to the baseline, excluding intra-EU trade, results in volume. USA part of the Paris agreement. Source : MIRAGE-VA, author's calculations.

in the EU, both in the industry and in the rest of the economy, and the "servicification" of the economy which is somehow the other face of its decarbonation. We expect an "electrification" of the economy and an increase in the value added of services. All these elements nicely show up in Figure 1. There is a large increase in the value added generated by the electricity sector (19%), business services (19%) and of other services (29%). The other side of the coin is the deleterious impact of the CBA on i) carbon intensive industries (metals: -6%, chemicals: -6%, other energy intensive industries: -2%) and ii) on downstream industries intensive in intermediate products sourced from ETS sectors (e.g.: -3%). The first impact is the net outcome of two opposite effects: the protection offered by the CBAM and the drop in demand due to higher prices of carbon. The second impact is better understood when one recalls that foreign competitors competing downstream (mainly in automotive industry and textiles) do not pay for the carbon at home and are not subject to the CBAM, while EU competitors pay their intermediate consumptions at a higher price because of the CBAM.

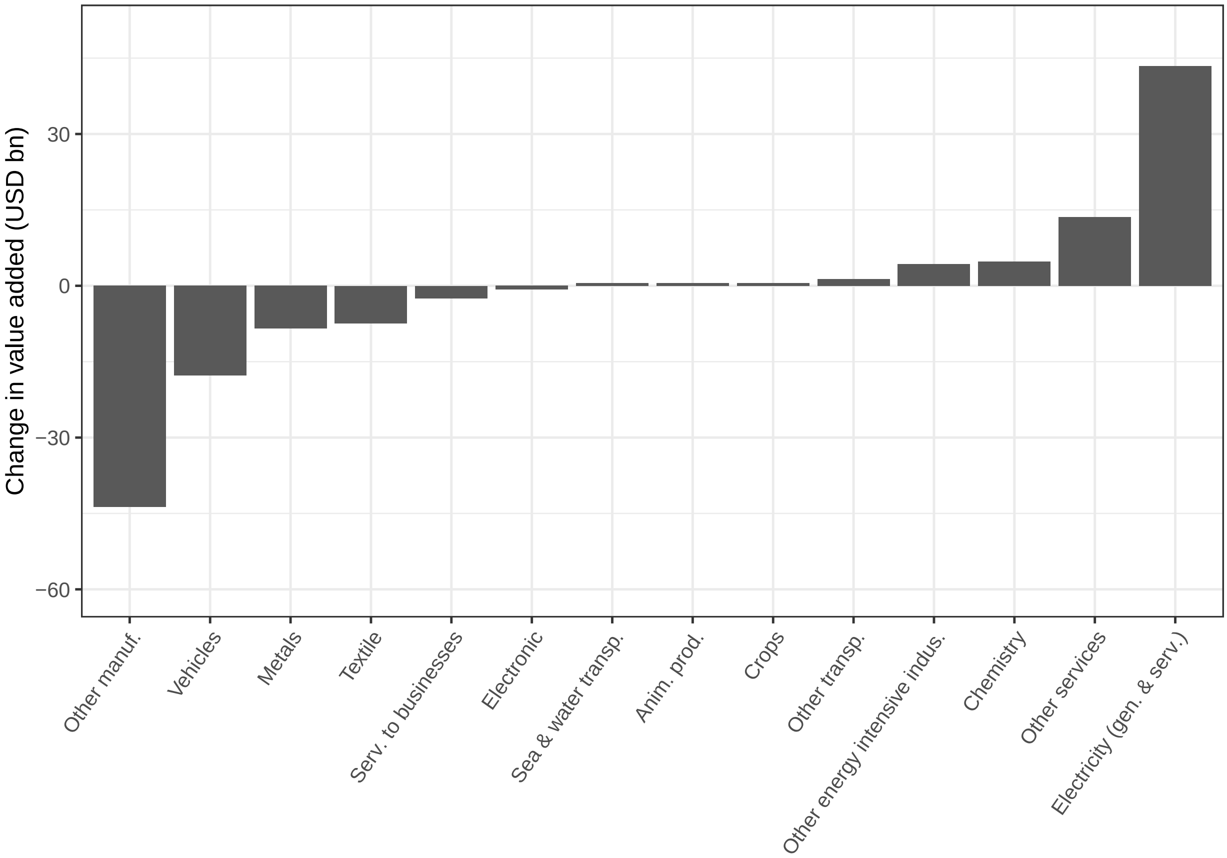
Figure 2 illustrates the impact of the CBAM complemented by the rebate. As already mentioned, the addition of the rebate magnifies the consequences of the CBAM. It subsidies the exports of energy intensive goods, which can even have a competitive advantage with respect to the same goods in produced in country with an ambitious climate policy but without a carbon adjustment mechanism at its own borders, like Canada or Japan. As a result, the sectors *Chemicals* and *Other energy intensive industries* now increase their value added. At the same time, the losses in value added in downstream industries, those that use goods covered by the ETS as intermediate consumptions, are even larger. These sectors are further penalised by the larger increase in the carbon prices in the ETS, which augments the cost of their intermediate consumptions and raises their production costs. As a consequence, downstream sectors loose market shares both on export markets and on the domestic European market. The losses in VA in the sector *Other manufactured*

Figure 1: Impact of the CBAM on the EU value added, by sector, in 2040



Source: simulations made with MIRAGE-VA, author's calculations. Only variations greater than USD 500 million are represented. Changes with respect to the reference scenario, in volume.

Figure 2: Impact of the CBAM *associated with a partial rebate* on the EU value added, by sector, in 2040



Source: simulations made with MIRAGE-VA, author's calculations. Only variations greater than USD 500 million are represented. Changes with resepct to the reference scenario, in volume.

products now exceed USD 40 billion in 2040, and those in the automotive sector, one of the main users of metals, in particular steel, are larger than USD 15 bn.

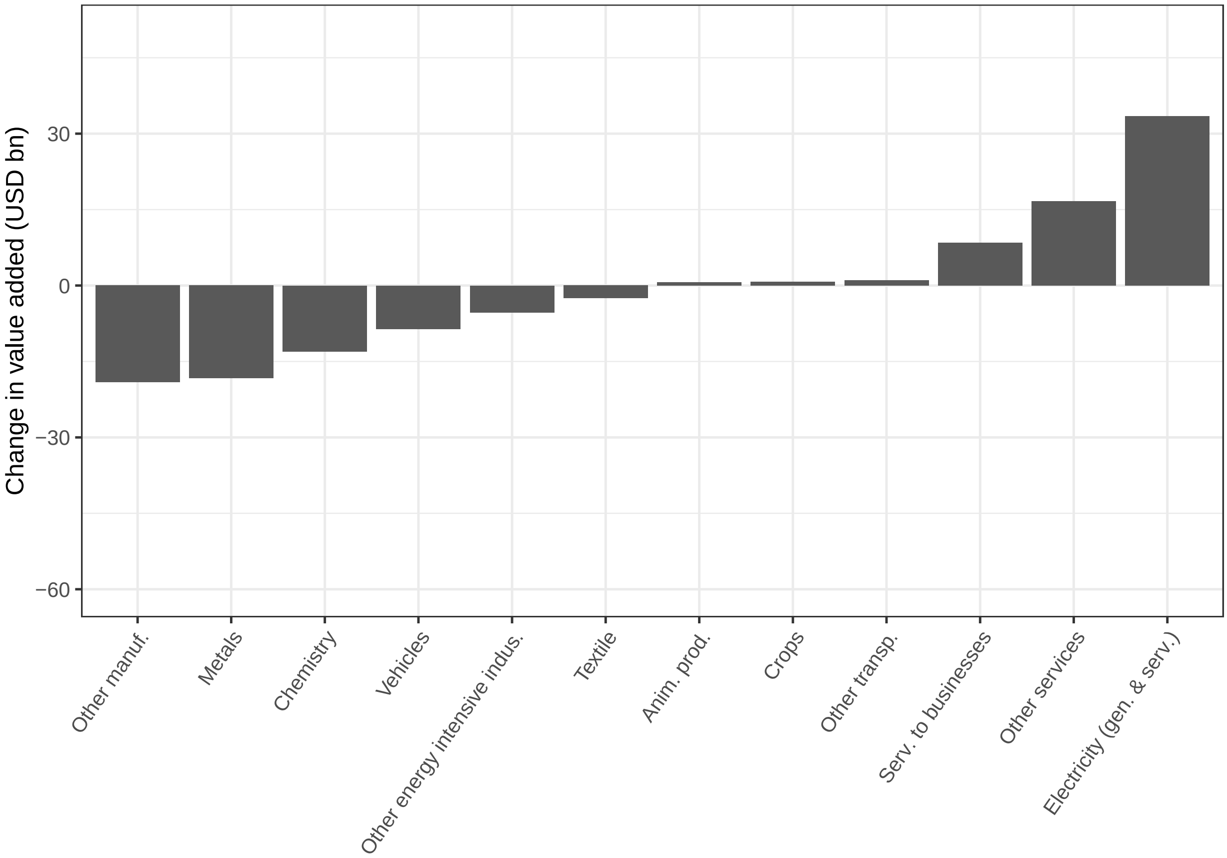
Figure 3 illustrates the impact of the CBAM embarking a SDT for LDCs. The outcome is just a lighter version of the CBAM, with no significant different impact on the sectors.

It is now worth focusing on the environmental impact of the CBAM, using the reduction in global GHG *leakages* as a metric of the efficiency of the instrument. The mechanism actually reduces the *global leakages* caused by the implementation of the Paris Agreement.[30] Considering *cumulated* emissions over the period from 2023 to 2040, the reduction reaches −22% and amounts to 7 $GtCO_2eq$, corresponding to around 2 years of European emissions, as reported in Table 2.[31] Even if impressive, this reduction of leakages remains smaller by one order of magnitude than the reduction in cumulated global emissions caused by the return of the US in the Paris Agreement.

[30]Leakages result from the increase in GHG emissions in unconstrained countries following the implementation of climate policies in the countries that have taken unconditional commitments under the Paris Agreement. In our modelling framework, we account for both direct and indirect leakages but cannot directly distinguish between these two kinds of leakage.

[31]European emissions amounted to 3.7 $GtCO_2eq$ in 2019, according to the European Environment Agency.

Figure 3: Impact of the CBAM *combined with a SDT* on the EU value added, by sector, in 2040



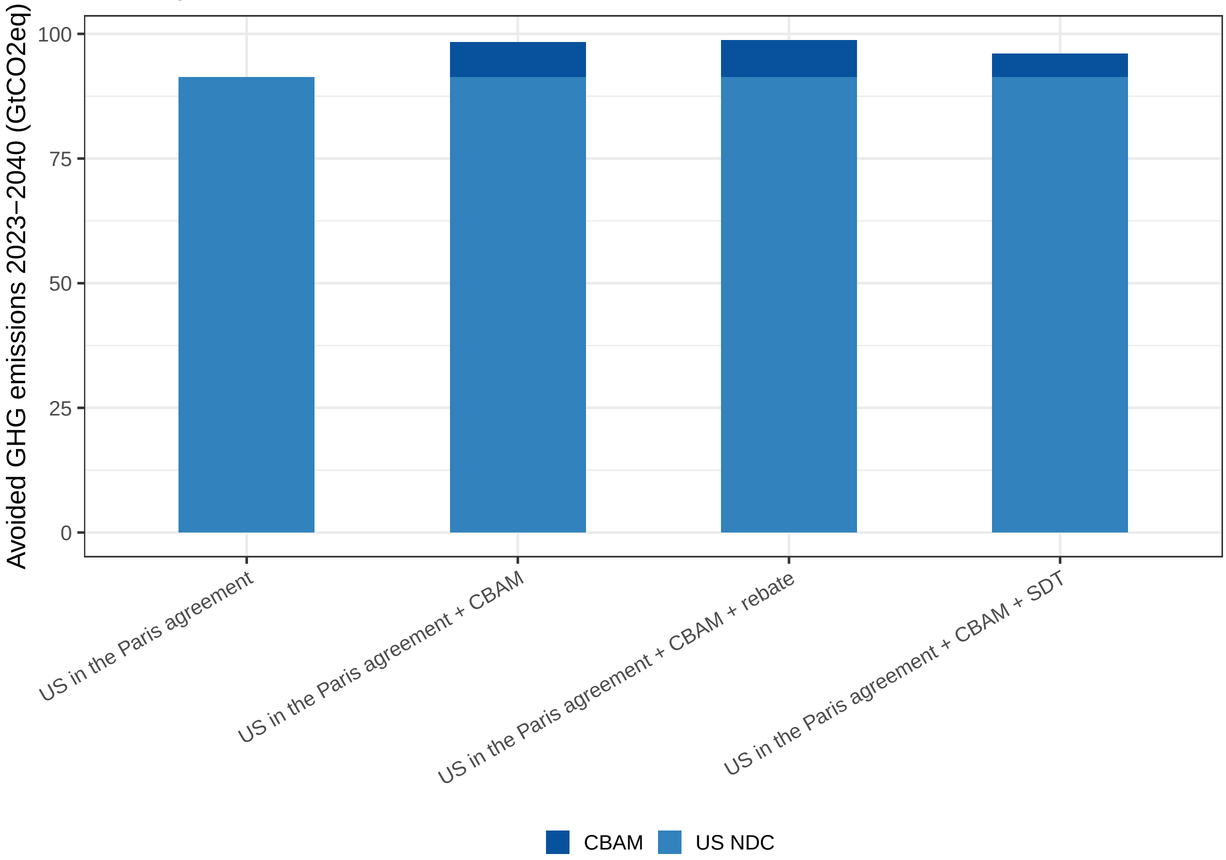
Source: simulations made with MIRAGE-VA, author's calculations. Only variations greater than USD 500 million are represented. Changes with respect to the reference scenario, in volume.

Table 2: Global GHG leakage in different scenarios

Climate policy	GHG leakage (Mt CO2eq)	Var. in GHG leakage (%)
The US participates in the Paris Agreement		
Paris Agreement	32,091	
Paris Agreement + EU CBAM	25,105	−22
Paris Agreement + EU CBAM + rebate	24,801	−23

Notes: cumulated leakages over the period 2023–2040. Variation, in %, with respect to the leakages generated by the fullfillment of the commitments taken in the Paris Agreement.
Source: simulations made with MIRAGE-VA, author's calculations.

Figure 4: GHG emissions avoided, with respect to a situation in which the US does not participate in the Paris Agreement



Source: simulations made with MIRAGE-VA, author's calculations. Cumulated emissions over the period 2023-2040.

This drop in global emissions is represented by the light (initial commitments) and medium (announcements of April 2021) blue bars in Figure 4. It indicates that the implementation of the US commitments under the Paris Agreement avoid the emission of 91.3 $GtCO_2$eq at the global level, cumulated over the 2023–2040 period, which corresponds to 20 months of contemporary world GHG emissions.[32] This large difference between the impact of the CBAM (in dark blue) and the one of the return of the US in the Paris agreement recalls that the main lever of an ambitious climate policy is actually the incentive for large emitters to join the effort. Even if it reduces by one fourth the leakage caused by the implementation of the Paris Agreement at the global level, the EU CBAM that we simulate does not reduce significantly global emissions.

[32]Global emissions amounted to 55.3 Gt CO_2eq in 2018, according to the United Nations.

Conclusion

Taking stock of the move of the European Parliament and the Commission towards a compensation of carbon at the borders of the EU, this paper simulates the environmental and economic impact of different options of implementation of this mechanism. We explore the impacts on GDP, trade, value added and carbon leakages. Considering the trajectory of the world economy in terms of GDP and induced emissions in absence of any abatement policy, we impose the caps on emissions corresponding to the (updated) unconditional NDCs of the Paris agreement. This is our reference. The counterfactuals consist in i) a CBAM limited to direct emissions and based on EU reference emissions; ii) augmented by a rebate of allowances purchased on the ETS market to European exporters; ii) or alternatively augmented by a Special and Differential Treatment. We show that the CBAM is efficient in reducing carbon leakages, which is the purpose of the tool as announced by the European commission. The cumulated leakages associated with the Paris agreement are reduced by the equivalent of two years of European emissions over the period 2023-40 considered here in our first scenario. This however comes at a cost in terms of GDP for the EU, as this additional distortion hampers the competitiveness of downstream industries. The comparison of the outcome of the CBAM with the return of the US in the Paris agreement shows that embarking the largest emitters in the effort should be the ultimate objective of an ambitious environmental policy.

Bibliography

Antimiani, A., Costantini, V., Martini, C., Salvatici, L. & Tommasino, M. C. (2013), 'Assessing alternative solutions to carbon leakage', *Energy Economics* **36**, 299–311.

Babiker, M. H. & Rutherford, T. F. (2005), 'The economic effects of border measures in subglobal climate agreements', *The Energy Journal* **26**(4).

Bellora, C. & Fouré, J. (2019), Trade, global value chains and the Paris Agreement. mimeo.

Böhringer, C., Garcia-Muros, X., Cazcarro, I. & Arto, I. (2017), 'The efficiency cost of protective measures in climate policy', *Energy Policy* **104**, 446–454.

Böhringer, C., Schneider, J. & Asane-Otoo, E. (2021), 'Trade in carbon and carbon tariffs', *Environmental and Resource Economics* .

Böhringer, C., Bye, B., Fæhn, T. & Rosendahl, K. E. (2012), 'Alternative designs for tariffs on embodied carbon: A global cost-effectiveness analysis', *Energy Economics* **34**, S143–S153.

Böhringer, C., Carbone, J. C. & Rutherford, T. F. (2012), 'Unilateral climate policy design: Efficiency and equity implications of alternative instruments to reduce carbon leakage', *Energy Economics* **34**, S208–S217.

Böhringer, C., Carbone, J. C. & Rutherford, T. F. (2018), 'Embodied carbon tariffs', *The Scandinavian Journal of Economics* **120**(1), 183–210.

Bouet, A., Decreux, Y., Fontagné, L., Jean, S. & Laborde, D. (2008), 'Assessing applied protection across the World', *Review of International Economics* **16**(5), 850–863.

Elliott, J., Foster, I., Kortum, S., Munson, T., Perez Cervantes, F. & Weisbach, D. (2010), 'Trade and carbon taxes', *American Economic Review* **100**(2), 465–69.

Felder, S. & Rutherford, T. (1993), 'Unilateral CO_2 reductions and carbon leakage: the consequences of international trade in oil and basic materials', *Journal of Environmental Economics and Management* .

Fontagné, L., Fouré, J. & Ramos, M. P. (2013), MIRAGE-e: A general equilibrium long-term path of the world economy, Working Paper 2013-39, CEPII.

Fontagné, L., Mitaritonna, C. & Signoret, J. E. (2016), Estimated tariff equivalents of services NTMs, Working Paper 2016-20, CEPII.

Fouré, J., Bénassy-Quéré, A. & Fontagné, L. (2013), 'Modelling the world economy at the 2050 horizon', *Economics of Transition* **21**(4), 617–654.

Fouré, J., Guimbard, H. & Monjon, S. (2016), 'Border carbon adjustment and trade retaliation: What would be the cost for the European Union?', *Energy Economics* **54**, 349–362.

Garicano, L. (2021), Towards a feasible carbon border adjustment mechanism: Explanation and analysis of the European Parliament's proposal. Mimeo, European Parliament.

Gollier, C. & Tirole, J. (2015), 'Negotiating effective institutions against climate change', *Economics of Energy & Environmental Policy* **4**(2).

Guimbard, H., Jean, S., Mimouni, M. & Pichot, X. (2012), 'MAcMap-HS6 2007, An exhaustive and consistent measure of applied protection in 2007', *International Economics* **130**, 99–121.

Hertel, T., Hummels, D., Ivanic, M. & Keeney, R. (2007), 'How confident can we be of CGE-based assessments of free trade agreements?', *Economic Modelling* **24**(4), 611–635.

Hyman, R. C., Reilly, J. M., Babiker, M. H., De Masin, A. & Jacoby, H. D. (2003), 'Modeling non-CO_2 greenhouse gas abatement', *Environmental Modeling & Assessment* **8**, 175–186.

Kee, H. L., Nicita, A. & Olarreaga, M. (2008), 'Estimating trade restrictiveness indices', *The Economic Journal* **119**(534), 172–199.

Kuik, O. & Hofkes, M. (2010), 'Border adjustment for european emissions trading: Competitiveness and carbon leakage', *Energy policy* **38**(4), 1741–1748.

Manders, T. & Veenendaal, P. (2008), Border tax adjustments and the EU-ETS. A quantitative assessment, CPB Document 171, Netherlands Bureau for Economic Policy Analysis.

Markusen, J. R. (1975), 'International externalities and optimal tax structures', *Journal of international economics* **5**(1), 15–29.

McKibbin, W. J., Morris, A. C., Wilcoxen, P. J. & Liu, W. (2018), 'The role of border carbon adjustments in a U.S. carbon tax', *Climate Change Economics* **09**(01), 1840011.

Monjon, S. & Quirion, P. (2011), 'Addressing leakage in the eu ets: Border adjustment or output-based allocation?', *Ecological Economics* **70**(11), 1957–1971.

Nordhaus, W. (2015), 'Climate clubs: Overcoming free-riding in international climate policy', *American Economic Review* **105**(4), 1339–70.

Walmsley, T. & Minor, P. (2016), ImpactECON 002 rev. 2 Supply chain database, data and model documentation, Technical report, ImpactECON.

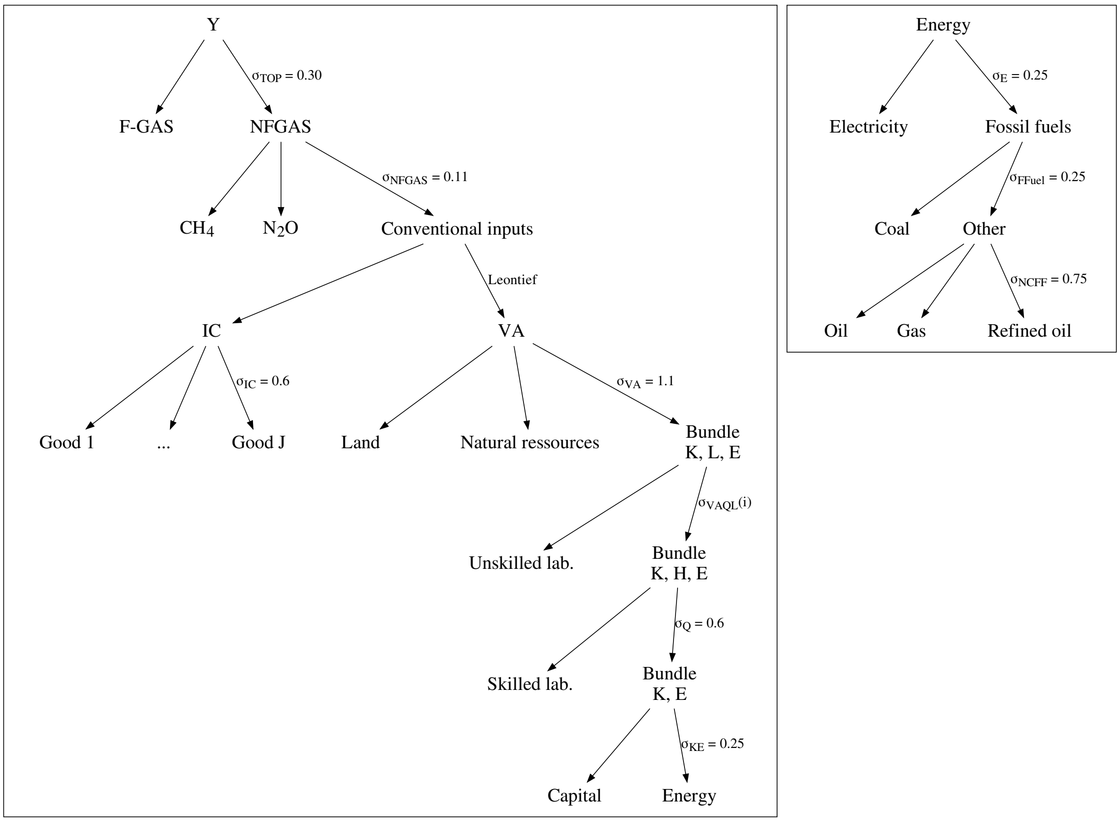
Weitzel, M., Hübler, M. & Peterson, S. (2012), 'Fair, optimal or detrimental? Environmental vs. strategic use of border carbon adjustment', *Energy Economics* **34**, S198–S207.

A Appendix

A.1 The production function in MIRAGE-VA

Figure A1 shows the nesting of the CES and Leontief functions used to represent the production function of industrial goods that are not considered as energy intensive and of services.

Figure A1: Structure of the production function for manufacture sectors and services in MIRAGE-VA



A.2 The aggregation

Table A1: The regional and sector aggregation.

Regions	Sectors
Australia New-Zealand	Oil
Canada	Refined oil
China	Coal
EU 27	Gas
India	Electricity (distrib.)
Japan	Other primary prod.
Korea	Crops
Mexico	Cattle and animal prod.
USA	Forestry
Asia Intensity	Beverages tobacco
Asia BAU	Other food prod.
Rest of Asia Oceania	Metal products
Latin America Absolute	Chemicals
Latin America Intensity	Other energy intensive manuf. prod.
Latin America BAU	Textile
North-Africa BAU Middle-East	Vehicles
Rest of North-Afr. Middle-East	Electronic
Sub-Saharan Africa BAU	Other manuf. prod.
Rest of Sub-Saharan Africa	Business services
Rest of Americas	Air transport
Rest of Europe Absolute	Maritime transport
Rest of Europe nes	Other transport
RoW Absolute	Other services