

EU in Search of a WTO-Compatible Carbon Border Adjustment Mechanism*

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Abstract

Achieve carbon neutrality by 2050 not only raises challenging compliance issues for European producers in carbon-intensive industries, but also the compatibility of the Carbon Border Adjustment Mechanism (CBAM) with the rules set in the framework of the World Trade Organisation (WTO). The CBAM is intended to avoid massive carbon leakages, restore the level playing field and make the taxation of carbon acceptable from a political economy perspective. Such mechanism has been announced mid-July 2021 by the European Commission. The general principle is to put a price on carbon contained in imported products whose production-related emissions have not been taxed (or not at the same level as in the European Union) by the exporter country, in order to compensate for the difference in carbon prices at the border of the European Union. This paper aims to quantify the economic and environmental efficiency of this mechanism and to shed light on the consequences of the different choices to be made in terms of its design. Different from the previous literature, we evaluate these various options with a dynamic general equilibrium model featuring imperfect competition, global value chains, green-house gas emissions and endogenous price of emission quotas. We highlight the trade-off between ambition and WTO compatibility of the mechanism. As the CBAM will lead to a sizeable increase in the price of carbon quotas in the ETS market, losses in the competitiveness of downstream industries are expected. Lastly, bilateral export losses for some trading partners will drive them to challenge the mechanism at the WTO.

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

JEL Codes: F14, F13, F17, Q56.

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Introduction

The tension between ambitious commitments to reduce global Green-House Gas (GHG) emissions and the maintenance of the open multilateral trading system is becoming a major political issue. 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 illustration of the “tragedy of the commons” (Gollier & Tirole 2015). This lack of incentive resorts to the political economy: governments have to make GHG taxation acceptable to their constituents and bearable by their companies in the absence of international coordination. Indeed, the Carbon Border Adjustment Mechanism (CBAM hereafter) would be challenging to enforce a much higher taxation of carbon, as the one implied by the European Green Deal, without treating domestic and imported products on the same foot.¹ In the same vein, from the environmental perspective, it would not be acceptable to reduce GHG emissions in the European Union (EU) by simply displacing them to countries with less ambitious climate policies.

As a consequence, among the package of 13 regulations announced mid-July 2021 by the European Commission in order to reach the objective of climate neutrality by 2050, the CBAM occupies a prominent place: on the top of avoiding carbon leakages – its official motivation – it indeed also seeks to make carbon taxation acceptable at high rates in Europe by levying an equivalent tax on imported products. Such attempt will however raise both the difficult question of its compatibility with the multilateral rules of international trade and the opposition of European businesses to its design and their preference for the *status quo* in any event.

The CBAM comes as a complement to the central tool of the European Union’s climate policy, the Emissions Trading Scheme (ETS), which in mid-July 2021 the European commission proposed to extend to other activities (maritime and road transport, and heating) on a distinct market. The ETS, set up in 2005, is a carbon market² 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 40% by 2030, with respect to 1990. Of course, efforts on other sectors are also set to reach the commitment taken by the EU in the Paris Agreement to reduce by 55% its GHG emission in 2030, with respect to 1990.

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.*

²GHG covered by the ETS are: carbon dioxide (CO₂), nitrous oxide (N₂O) 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 CO₂ equivalents, noted CO₂eq.

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 exporter country. The ENVI Committee of the European Parliament voted a first resolution in this sense on 4 February 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 which finally occurred in July 2021. The adopted text 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, formally announced by the Commission on 14 July 2021, is broadly in line with the proposal of the Parliament, with some meaningful differences such as the objective of phasing out of free allowances,⁵ the reference emissions used for compensation, the coverage of ETS sectors, the coverage of products incorporating ETS products as intermediate consumption, and the absence of a Special and Differential Treatment (SDT) for Least Developed Countries (LDCs). The purpose of this regulation is set as follows: “A carbon border adjustment mechanism (“CBAM”), announced in the European Green Deal, is part of that package and will serve as an essential element of the EU toolbox to meet the objective of a climate-neutral EU by 2050 in line with the Paris Agreement by addressing risks of carbon leakage as a result of the increased Union climate ambition.” (Art. 1.1).

The Commission envisaged different designs of the mechanism and concluded with a scheme combining 1) the purchase of allowances by importers on a specific market, price taker with respect to ETS; 2) a taxation base equal to the emissions of the exporter, inclusive of indirect emissions associated to the energy mix of the electricity consumed in the production process;⁶ 3) a tax rate

³The 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.

⁴Art 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 (...). ”

⁵In absence of adjustment at the border, free allowances of emission quotas to energy intensive industries reduced the risk of carbon leakage (Böhringer, Carbone & Rutherford 2012).

⁶“the carbon price of imports is based on actual emissions from third country producers rather than on a default value based on EU producers’ averages”

(the number of allowances to be purchased by the importer) net of any taxation by the exporting country of the carbon incorporated in the product; 4) the phasing out of free allowances over a ten years period, progressively replaced by the CBAM during that period; 5) the absorption in the European budget of the resources generated by the CBAM in order to “(...) address the challenges posed by the COVID-19 pandemic and, therein, support investment in the green and digital transitions”.

The mechanism raises three questions: i) how to reduce direct and indirect international carbon leakage induced by EU climate policy (as acknowledged in the above-mentioned Article 1.1); ii) how to restore a level playing field for EU producers having to purchase emission allowances in the ETS; iii) and how best to design the mechanism in such a way as to minimise the likelihood of WTO panels or simply the prospect of retaliation from trading partners.

Regarding the first question, a distinction has to be made between direct and indirect leakages. The emitting European industries may displace part of their production in regions where the climate policy is less tight than the new European ambitions, while imports from non-taxing countries may partly substitute for European production. Such direct leakage would jeopardize European efforts, while increased imports of carbon-intensive products would widen the gap 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. A second type of leakage (Felder & Rutherford 1993) may jeopardize the impact of EU efforts: the lower demand for fossil fuels in Europe will in turn depress prices of fossil fuels, leading *indirectly* to higher consumption by non-constrained countries, hence higher GHG emissions.⁷ Against this background, it is worth quantifying the share of leakages (both direct and indirect) that will be avoided due to the CBAM. But to do so, we need a global model taking account of emissions in all countries, and of the reaction of carbon price in Europe to the substitution of European goods to imported goods and thus a higher demand for emission allowances on the ETS.

Regarding the second question, a distinction must be made between the level playing field for carbon intensive sectors, and the level playing field for downstream sectors. Carbon intensive sectors will benefit from the protection of the CBAM on the European internal market. But how to avoid the loss of competitiveness of European exporters of carbon intensive sector on third markets? Indeed, the CBAM will not compensate European producers of ETS products for the high price of emission allowances, the more so that this price will increase as a result of the CBAM, even if the

⁷This 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.

importers buy allowances on a market separate from the ETS one as will be demonstrated below. Thus, should one complement the CBAM with export rebates for European exporters to restore the level playing field on extra-EU markets?⁸ As for downstream sectors that use carbon intensive products as inputs the problem is even trickier – think of the steel used in the car industry for instance. Partial product coverage of the CBAM implies that European downstream manufacturers will have to pay a higher price for their inputs, regardless of whether those inputs are sourced in Europe or in third Countries. In total, CBAM would distort value added to the benefit of European upstream producers, at the expense of their European clients. To give an order of magnitude of this loss of competitiveness and the resulting decrease in the value added of the end-products industries, it is essential to have a model in which the value chains are duly represented.

Finally, with regard to compliance with WTO rules and the potential reaction of third countries, a compromise must be found between the effectiveness of the mechanism and legal certainty. Imports from different countries will have to purchase different amounts of allowances, which does not necessarily violate the non-discrimination principle given that a common mechanism will be used. The potential problem is that the only criterion taken into account is the price of carbon, whereas there is a continuum of policies to reduce emissions, ranging from carbon price only to regulation only or subsidies. An exporter country may well claim that it will reach the same goal with a different instrument and hence should not be taxed. Another issue is the basis (the reference emissions) for compensation: EU producers will purchase allowances based on European emissions, while third country competitors will be charged on the basis of higher emissions, especially exporters in the developing world. Without special and differential treatment, this will penalise countries with limited resources to combat climate change. Relying on the exporting country's emissions also increases the cost of their exports to the EU market, making it more likely to be challenged at the WTO and even subject to commercial sanctions. Finally, there are two risks in terms of WTO compatibility. The first, which relates to the introduction of export rebates, has been avoided in the Commission's proposal. But this involves a loss of competitiveness for European exporters of ETS products. The second, surprisingly, has not been considered in the Commission's proposal, probably because of political equilibria within the EU and a majority to be found at the European Council. We are referring here to the allocation of the

⁸Combining a cap-and-trade system (the ETS) with a carbon compensation 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 mechanism at the border 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.

resources generated by the compensation mechanism. The legal logic is that the resources should be allocated to support climate change mitigation, and the economic logic is that they should be allocated where the effectiveness of decarbonisation expenditure is greatest, namely in developing countries. Despite these considerations, the proposal made by the European Commission in July 2021 plans to allocate the resources to the EU budget and to use them to cover part of the Covid debt.

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 of the affected sectors. Our contribution to the literature is to assess the effectiveness of the various possible designs of the CBAM in meeting the environmental objectives and to quantify their economic impacts, with a focus on the three questions listed above. Our modelling features a reference path for the world economy till 2040; it links trade and GHG emissions taking stock of Global Value Chains (GVCs), 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 GVCs 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, taking into account the announcements made during the Washington Summit, on 22 April 2021. But there is an important restriction: in order to stick to the argument of the Commission – a CBAM is needed due to the lack of ambition of Europe’s trading partners – we consider only carbon pricing in those countries having implemented *national* schemes of taxation. When carbon pricing

is restricted to a province, or even to a couple of cities, we interpret such lack of commitment as the impossibility to reach the NDCs. The selection of countries is based on the data provided by the World Bank.⁹ This second step constitutes our baseline: a world growing till 2040 where a sub-sample of countries abate their emissions according to their NDCs.

Then, we implement in a third step a CBAM at the border of the EU, here modelled as an import tax replicating the price of carbon on the ETS market. We consider different perimeters of emissions (direct emissions, versus direct and indirect energy-related ones), different references for emissions (EU average versus exporter country average), with or without rebate to EU exporters, with or without Special and Differential Treatment for least developed countries. In all simulations free allowances are absent, because we think that the ten years phasing out envisaged will hardly fit WTO rules, but the revenues of the CBAM are allocated to the European budget, as envisaged by the Commission. In a first experiment, all industries covered by the European scheme of emission quotas are covered by the CBAM,¹⁰ and we take on board the direct emissions associated with the use of energy in these industries. Reference emissions are the European average. In a second experiment, we add energy-related indirect emissions, using reference emissions from the EU here again.¹¹ A rebate of allowances purchased on the ETS market to European exporters is envisaged in a third experiment.¹² In a fourth experiment, we use the reference emissions of the exporter country.

In all experiments we exclude low income exporters from any compensation at the European border, in line with the usual SDT principle at the WTO, and with the recommendation of the European Parliament.¹³

To proceed, we use the MIRAGE-VA model, developed at CEPPII (Bellora & Fouré 2019). It is a global, dynamic, multi-sectoral and multi-regional model, featuring 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.

⁹ *Carbon Pricing Dashboard*, <https://carbonpricingdashboard.worldbank.org/>

¹⁰The Commission is less ambitious to begin with: “Whilst the ultimate objective of the CBAM is a broad product coverage, it would be prudent to start with a selected number of sectors with relatively homogeneous products where there is a risk of carbon leakage.”

¹¹The European commission suggests using the electricity mix of the exporter country, which may be difficult to implement and subject to contentious issues of energy subsidisation.

¹²Rebates were 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.

¹³Art. 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”.

In addition, energy is subject to independent productivity improvements, specifically calibrated. GHG emissions due to both energy use (carbon dioxide) and production processes (carbon dioxide, methane, nitrous oxide 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.¹⁴ 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 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 CO₂-taxes. Compensation is applied alternatively on Emission Intensive and Trade Exposed (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.¹⁵ 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 in-

¹⁴We 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”.

¹⁵We refer here to Countries that are listed in Annex I to the UN Framework Convention on Climate Change.

struments: 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, Wilcoxon & 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, Guimbarde & Monjon (2016) take a slightly different 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. Lastly the proposal of the Commission is backed by an impact assessment report using the JRC-GEM-E3 model. Different from us, there is 100% free allocation of carbon allowances to ETS industries in the reference scenario before implementation of the CBAM.

We contribute to this literature in four ways. First, we highlight policy options that sound to us like WTO-compatible. Second, we rely on a dynamic baseline of the world economy accounting for unconditional NDCs associated with the Paris agreement and for the effective implementation

of a carbon price at the national level in third countries. 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. Lastly, and importantly, carbon price is *endogenous* in the model and set to respect the cap of emissions associated with the unconditional NDCs in the baseline and in the different scenarios. A consequence is the adjustment of this price to the introduction of the CBAM, with cascading consequences for ETS producers and their downstream clients.

The remainder of this paper is organised as follows: section 1 provide all the details on the model we use and the data we rely on, as well as on the scenarios that we implement. Then, section 2 presents the economic and environmental results.

1 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.

1.1 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 change. It innovates by featuring GVCs and an improved representation of GHG emissions.¹⁶

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

¹⁶MIRAGE-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 dioxide. 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.

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.¹⁷ 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 1.3 provides details on data sources for each of these 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 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 9.¹⁸ This release of the GTAP database features 2011 as the last reference year. It

¹⁷Elasticities 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.

¹⁸The *ImpactECON Global Supply Chain package* allows converting the GTAP 9.0a 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 9.0a database is thus converted into a “Global Supply Chain Database”, a database of value of

represents the world economy considering 57 sectors in each of the 140 regions of its geographic decomposition. We aggregate this data into 23 sectors and 27 regions or countries (see Table A1 in the Appendix for the detailed aggregation).

1.2 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 1.4).

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 the increase in this latter price.

Carbon dioxide 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 dioxide, namely nitrous oxide, 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) (see details in Appendix A.1). Their substitution elasticity is taken from the literature.

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 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 (UNFCCC). We add here another important restriction, to stick to the spirit in which the European Commission conceived the CBAM, i.e. considering that its trading partners have developed climate policies which lack of ambition: we consider that only those countries that have already implemented, in 2021, a *national* carbon price scheme will fulfill the commitments they have taken in the Paris Agreement. This is equivalent to assume that those countries that, since 2016, have not priced nationally the carbon they emit will not be able, or will not have the political willingness, to reach their target in terms of GHG emission reduction. Based on the *Carbon Pricing Dashboard* developed by the World Bank, only 17 countries other than EU had national carbon pricing schemes in 2021: Argentina, Canada, Chile, Colombia, Iceland, Japan, Kazakhstan, Korea, Mexico, Montenegro, New Zealand, Norway, Singapore, South Africa, Switzerland, United Kingdom and Ukraine.¹⁹ China and the US only had subnational pricing schemes.²⁰ 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.²¹ 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.²² In other words, we consider

¹⁹South Africa made conditionnal commitments, and as such is not considered in our simulations as implementing a carbon pricing scheme.

²⁰Two days after the presentation of the *Fit for 55* package by the European Commission, China announced the implementation of its national carbon market. At this stage, our simulations do not consider China as reaching its target in terms of GHG emission reduction.

²¹The 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.

²²By 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

here that countries fulfill their commitments based on a cap-and-trade system, while they are actually free to choose the policy instruments they prefer.

Lastly as far as 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 cap imposed to the emissions of the sectors covered by the ETS is the one actually in force (and not the revised one, proposed by the Commission in July 2021), i.e. 40% in 2030 with respect to 1990. The level of the tax supported by sectors not covered by the ETS and on households is set to achieve the Paris target, conditional on the reductions undertaken in the ETS sectors. Note that we do not consider here free allowances to ETS sectors.

Unless otherwise specified, emission data are taken from the GTAP-E database and the satellite data on non-CO₂ emissions provided by GTAP.

1.3 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.

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.

1.4 The dynamic baseline

The effects of the EU CBAM are measured in terms of deviation from a dynamic baseline, using a 17 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. As said, we restrict the perimeter of countries achieving their unconditional NDCs to those having managed to set a carbon price at the national level in 2020. In this second step we also update the tariff protection to its level of 2013 (the most recent available in the MAcMap-HS6 database)²³ 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.²⁴ 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.²⁵

²³We 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.

²⁴We 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.

²⁵This 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

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 policy implemented in the scenario.

1.5 Scenarios

The central tool of European policy today is the ETS. This market concerns the Member States and a few other countries.²⁶ 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.²⁷ 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. The question raised by the new ambition of the Commission is how to best articulate this market with a compensation at the border.

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 (SDT) of the imports from Least Developed Countries (LDCs).

What scope? The European Parliament draft proposed 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.²⁸ The proposal of the Commission differs in restricting the perimeter of concerned ETS products (iron

departures from this consistency for certain “Rest of” regions. We also aggregated a couple of small size economies to larger groups for computational purposes.

²⁶Norway (the ETS represents only a small part of the taxation of this country), Liechtenstein and Iceland.

²⁷Remaining emissions must be curbed using other mechanisms.

²⁸“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 (...).”

and steel, aluminium, cement, fertilizers, electricity) but extending it to tubes and pipe fittings in order to avoid circumvention of the regulation. The indirect emissions induced by the consumption of electricity in the production process of ETS sectors are covered by the CBAM in the Commission proposal, based on the energy mix of electricity generation in the exporter country. The difficulty here is that the production of electricity might be subject to carbon taxation in the exporter country, which adds to the complexity of the compensation. Moreover, green electricity is heavily subsidized in Europe, which would open the Pandora box of subsidies in case of a panel at the WTO.

Which base? To ensure the effectiveness of the CBAM, it would be appropriate to use the actual emissions of the exporter country. But 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). This was anyway the solution envisaged by the European Parliament, with reference to average global emissions.²⁹ The solution proposed by the Commission is to apply a default reference for emissions if the European importer is not in position to provide the requested information. An alternative solution would be to consider the average EU content. It 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. This solution is not envisaged by the Commission.

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 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

²⁹ 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.

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 and the Commission favor 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.³⁰ If the price is fixed, then the quantities of allowances on the second market should be adjusted.³¹

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.³² The proposal of the Commission is to not earmark the revenues of the CBAM and to allocate them in the general budget of the EU.

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 similar, from the point of view of economic analysis, to a consumption tax, without the problems of acceptability that this would raise.³³ However, rebating has an undesirable consequence: European

³⁰Garicano (2021) details the choices of the Parliament and explains the envisaged gradual phasing-out of free allowances.

³¹Art. 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”.

³²Art. 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.

³³A 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

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 remained 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.³⁴ The Commission proposal carefully disregards export rebates to ensure WTO compatibility. In the absence of a refund to exporters, CBAM cannot therefore be considered equivalent to a consumption tax.

Is the CBAM a substitute to free allocation of allowances to the industries of the ETS? The Commission is more affirmative than the Parliament on that front. But consistent with the Parliament, this principle of substitution being affirmed, the proposed implementation of the CBAM is progressive, over ten years, while free allowances would be progressively phased out in parallel. WTO compatibility of such approach is dubious and this approach may evolve after consultations with main trading partners and with the WTO.

Will imports from LDCs benefit from a SDT, for instance with an exemption of compensation? This option is disregarded at this stage by the Commission.

Against this background, we consider 4 scenarios summarized in Table 1. In all scenarios the CBAM is applied in 2023 on all sectors covered by the ETS.³⁵ And we systematically apply a SDT to LDCs, exempting them from the compensation. In the first scenario, we use as reference only emissions *directly* induced by the production process of these sectors. In order to maximise the chances of WTO compatibility we rely on the average EU emissions as a reference. There is no rebate to European exporters. In the second scenario the CBAM also compensates the indirect emissions induced by the generation of electricity used in the production process. The third scenario adds to the first a rebate to European exporters. Half of the allowances purchased to cover exports are rebated (recall that there are no free allowances in our scenarios). The last scenario differs from the first in terms of reference emissions: we consider the emissions of the exporter country.

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.

³⁴Art. 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”.

³⁵It will be difficult to justify at the WTO an exemption of certain ETS sectors that would be still subject to free allowances, hence this choice. Notice that the proposal of the Commission envisages a two-year implementation period whereby importers notify the embedded emissions of the imported products without having to purchase allowances. We disregard this two-year observation period by sake of simplicity.

Table 1: Scenarios

Scen.	Scope	Emissions	Tax base	Rebate	SDT
S1	All ETS sect.	Direct	EU	No	Yes
S2	All ETS sect.	Direct + indirect	EU	No	Yes
S3	All ETS sect.	Direct	EU	Yes	Yes
S4	All ETS sect.	Direct	Exporter	No	Yes

Table 2: Impact of the CBAM in EU

	CBAM (1)	+ Indir.emiss. (2)	+ rebate (3)	+ ref. exp (4)
GDP	-0.9	-0.8	-1.0	-0.7
Exports				
Exports int. goods	-4.8	-5.1	-2.9	-5.0
Exports final goods	-3.7	-5.4	-4.5	-8.8
Imports				
Imports int. goods	-4.3	-5.7	-3.8	-8.5
Imports final goods	-2.4	-2.6	-1.8	-2.8
Carbon price ETS	43.4	47.5	50.9	56.5
EU leakages	-30.0	-32.5	-31.1	-45.2
Global GHG (Gt CO ₂ eq)	-9.0	-9.8	-9.3	-13.6

Notes: relative changes in % compared to the baseline, in 2040, excl. price effect, excl. intra-EU, results in volume. International freight included. Changes in global GHG emissions are in absolute value, i.e. in Gt CO₂eq. Changes in leakages and global emissions are cumulated changes, computed over the period 2023 - 2040. Source: MIRAGE-VA, calculations by the authors.

2 Results

Table 2 provides a summary of the main macroeconomic and environmental impacts of our four scenarios, with a focus on the European economy. The baseline is the world economy in 2040, with all countries with unconditional NDCs and national carbon pricing capping their emissions according to those NDCs. The first column is showing the impact of the introduction in 2023 of the CBAM with no rebate to exporters, compensating only direct emissions and using EU average emissions as reference, and exempting LDCs in the name of SDT. There is indeed no double taxation of carbon embodied in imported products. The second column compensates also the indirect emissions linked to the generation of electricity use in the production process, relying again on average EU emissions for this additional tier. The third column adds to the first the rebate (50% of the purchased allowances) to EU exporters of ETS products. The fourth column replicates the first, but using as a reference the average emission in the exporter country.³⁶ All figures are in percentage deviation from the baseline in 2040, at constant prices. The first five rows report variations in economic variables, the last three ones variations in environmental variables.

The simplest CBAM (EU reference, direct emissions only, no rebate, SDT) achieves a 30%

³⁶In the proposal of the Commission individual exporters' emissions are targeted, which is out of reach with the data at hand, which justifies our approach. Considering the national average would also have the advantage to avoid that some exporters specialize their clean production for the European market, while other dirtier exporters reach other markets, leading to a kind of trade diversion, with no impact on the overall emissions of the exporting country.

reduction in carbon leakage, compared to the situation where the new European NDCs are enforced in absence of compensation at the border. The reference emissions chosen contribute to such modest achievement: using instead the reference emissions of the exporter country, the reduction in leakages is up to 45%. The complexity of the modalities envisaged to trace the carbon content of products in the EU proposal is accordingly justified by this difference in the outcome of the mechanism, although it is endangering its WTO compatibility.³⁷ In contrast, including indirect emissions, using the European energy mix as reference, has little impact (it reduces leakage by an additional two percentage points).

The other face of the coin is the impact of the CBAM on the carbon price in the ETS market. The simplest CBAM of scenario 1 leads to a 43% increase in the price of allowances on the main ETS market. Given that importers purchase allowance on a distinct (price taker) market, this outcome was not necessarily expected by the designers of the mechanism. But as EU ETS producers are going to respond to the additional demand substituting European inputs to imported inputs, they increase the demand for allowances, the latter being capped to respect the targets of the NDCs – hence the carbon price increases on the main ETS market, which indeed spills over the second market. 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. A more restrictive CBAM, using as a reference the exporter country emissions, will also increase by more the price of carbon (+56%), even more so than taking indirect emissions on board.

In order to give an order of magnitude of the leakages that would be avoided by the mechanism, we can cumulate the carbon leakages over the period covered by our analysis, i.e. 2023-40 and compare the situation with and without CBAM. This comparison shows that, in scenario 1, CBAM reduces the leakages induced by the Green Deal by 9 Gt, which is equivalent to almost three years of current European emissions (in 2020 the EU has emitted 3.6 Gt). Using the reference emissions of the exporting country would even avoid the equivalent of 4 years of European emissions.

As for the economic impact of the CBAM, the 0.9 percent drop in the EU GDP 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

³⁷The necessity for the importer to document the emissions in the origin country of the product, or conversely the need for exporters to register on a centralised database maintained by the Commission may be interpreted as additional non-tariff barriers.

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 lose 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 on third markets because the price of carbon in the EU increases. They accordingly reorient their sales towards their domestic market at the expense of their exports.

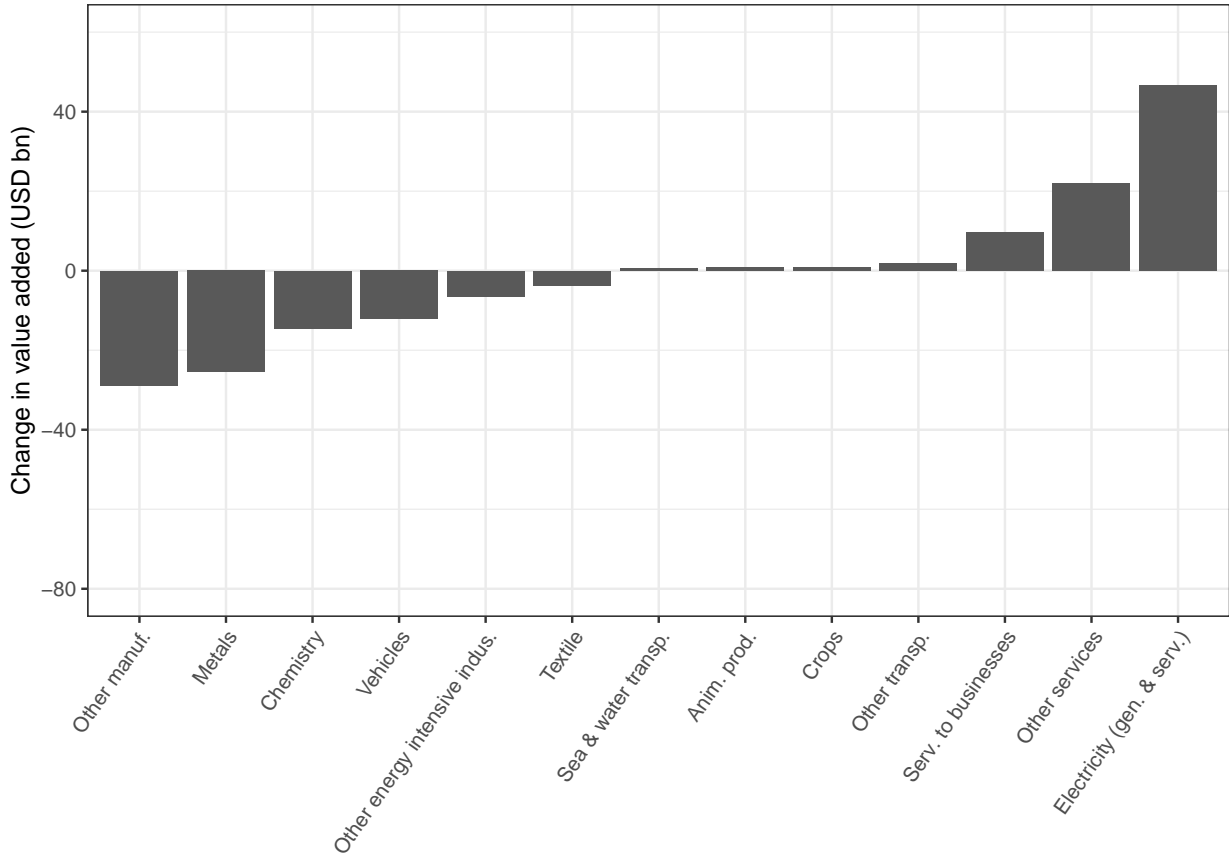
The design of the CBAM does curb these losses of efficiency. Taking into account the reference emissions of the exporting country, and not of the EU, corrects the distortion of competition better, thus reducing imports of intermediate goods more, and ultimately leading to a less pronounced decline in GDP. Again, offsetting indirect emissions as well does not make much difference to scenario 1 from an economic point of view. In contrast, a rebate to exporters mitigates the impact on exports of intermediate goods, but increases the economic cost of the mechanism.

Incidentally, the EU enjoys a positive terms of trade effect when introducing the CBAM. It varies between 0.2% in presence of the export rebate and 0.7% in scenario (4) where the emissions of the exporter country are chosen as reference. This effect, where the lower demand for carbon-intensive imports from a large country (the EU) results in lower import prices and therefore a positive terms-of-trade effect for this importer, is consistent with the theoretical prediction that the taxing country is extracting a rent from the exporters (Balistreri, Kaffine & Yonezawa 2019). This would also pose difficulties for the acceptance of the CBAM by WTO members.

We now look at the sectoral results. 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 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 decarbonization. We expect an “electrification” of the economy and an increase in the value added of services.

All these impacts of the CBAM in our first scenario nicely show up in Figure 1, which shows the

Figure 1: Impact of the CBAM on sectoral value added (*vs* baseline, in 2040). Scenario 1



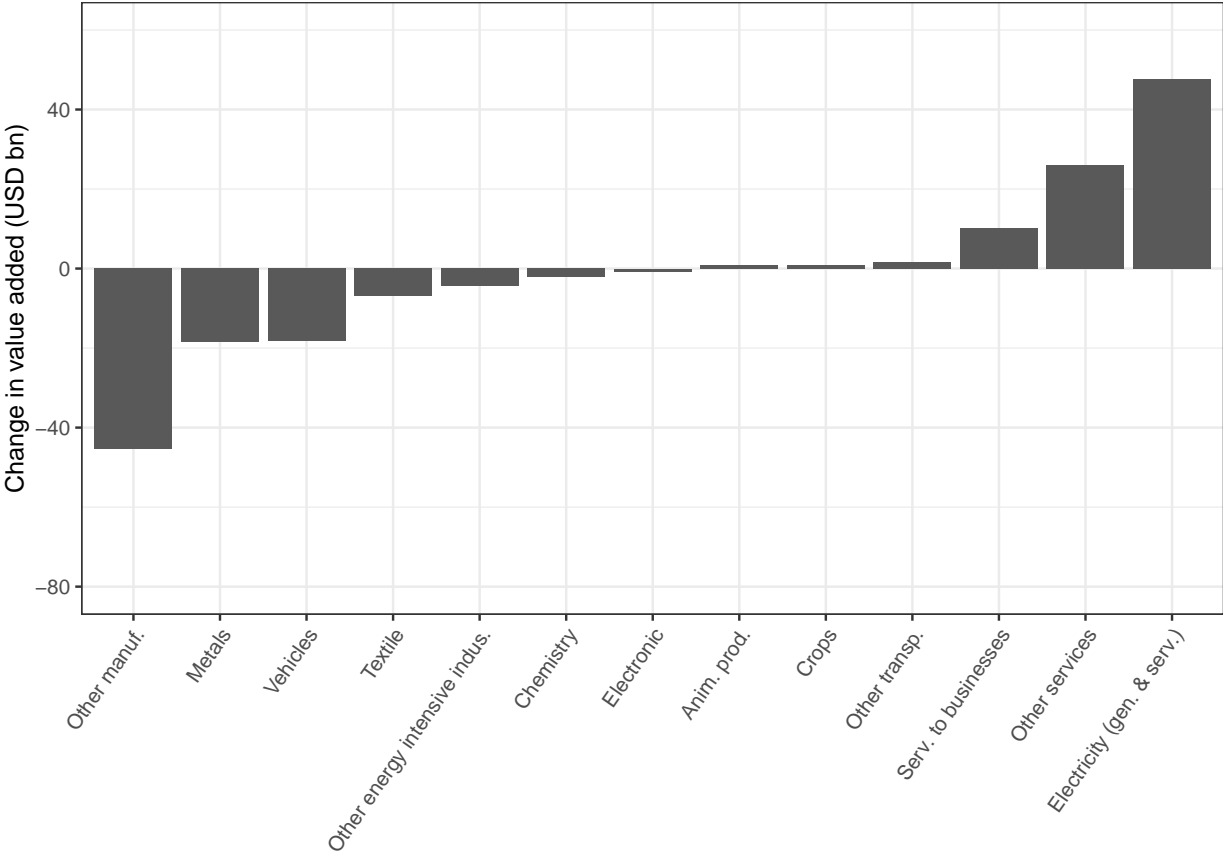
Source: simulations with MIRAGE-VA, calculations by the authors (var.> USD 50 Mn)

variation in 2040 (with respect to the baseline), in constant dollars, of the value added of sectors for which this variation exceeds 50 mn. There is a large increase in the value added generated by the electricity sector (22%). Other services and business services record large increases in value added in absolute terms, less so indeed in relative terms (0.2%). The other side of the coin is the deleterious impact of the CBA on i) carbon intensive industries (chemicals: -5% , metals: -2% , other energy intensive industries: -2%) and ii) on downstream industries intensive in intermediate products sourced from ETS sectors (other manufactured products: -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, -4% and -2% respectively) do not pay for the carbon at home and are not subject to the CBAM, while EU competitors pay their intermediate consumption at a higher price because of the CBAM.

Figure 2 is constructed on the same principles as 1 and illustrates the impact of the CBAM when indirect emissions are added to direct ones. Differences with scenario 1 are marginal.

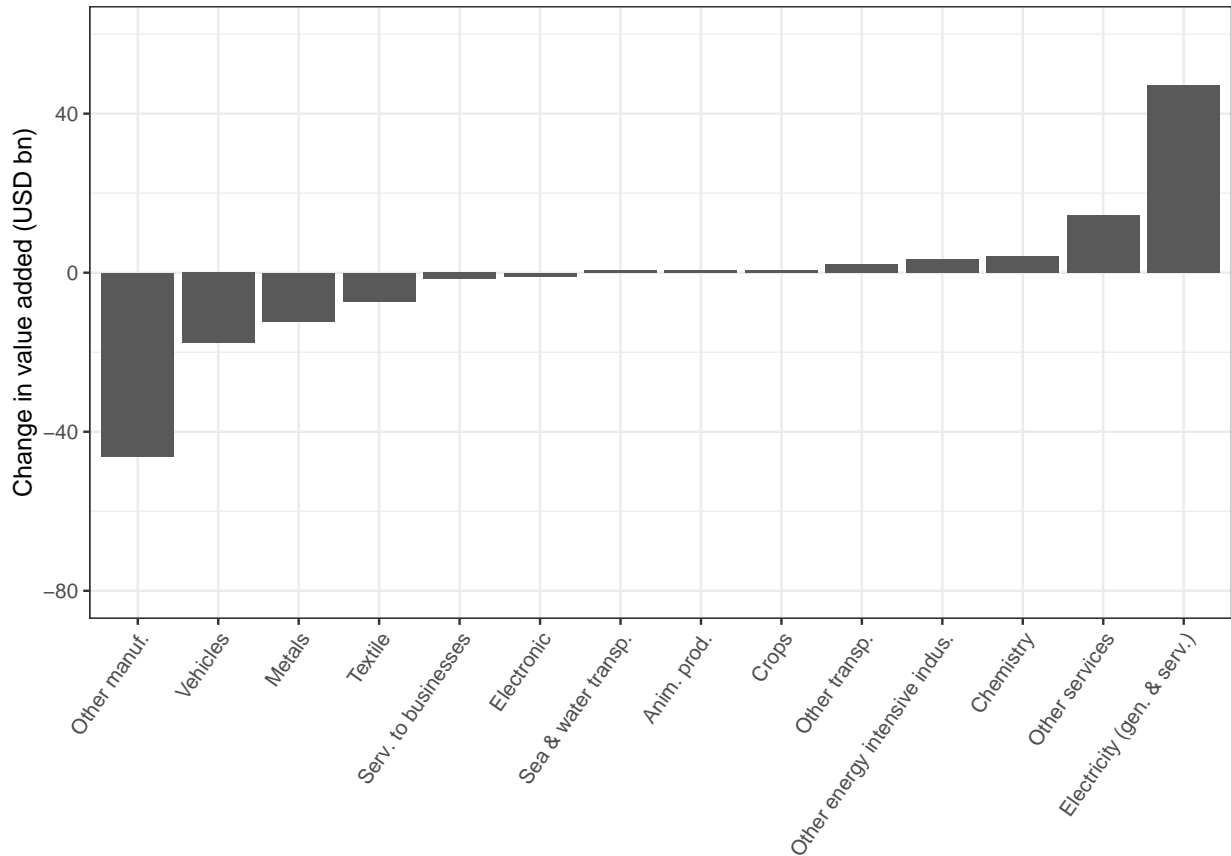
We illustrate in Figure 3 the impact of the CBAM complemented by the rebate as in scenario

Figure 2: Impact of the CBAM covering also indirect emissions on sectoral value added (vs baseline, in 2040)



Source: simulations with MIRAGE-VA, calculations by the authors (var. > USD 50 Mn)

Figure 3: Impact of the CBAM *with rebate* on sectoral value added (*vs* baseline, in 2040)

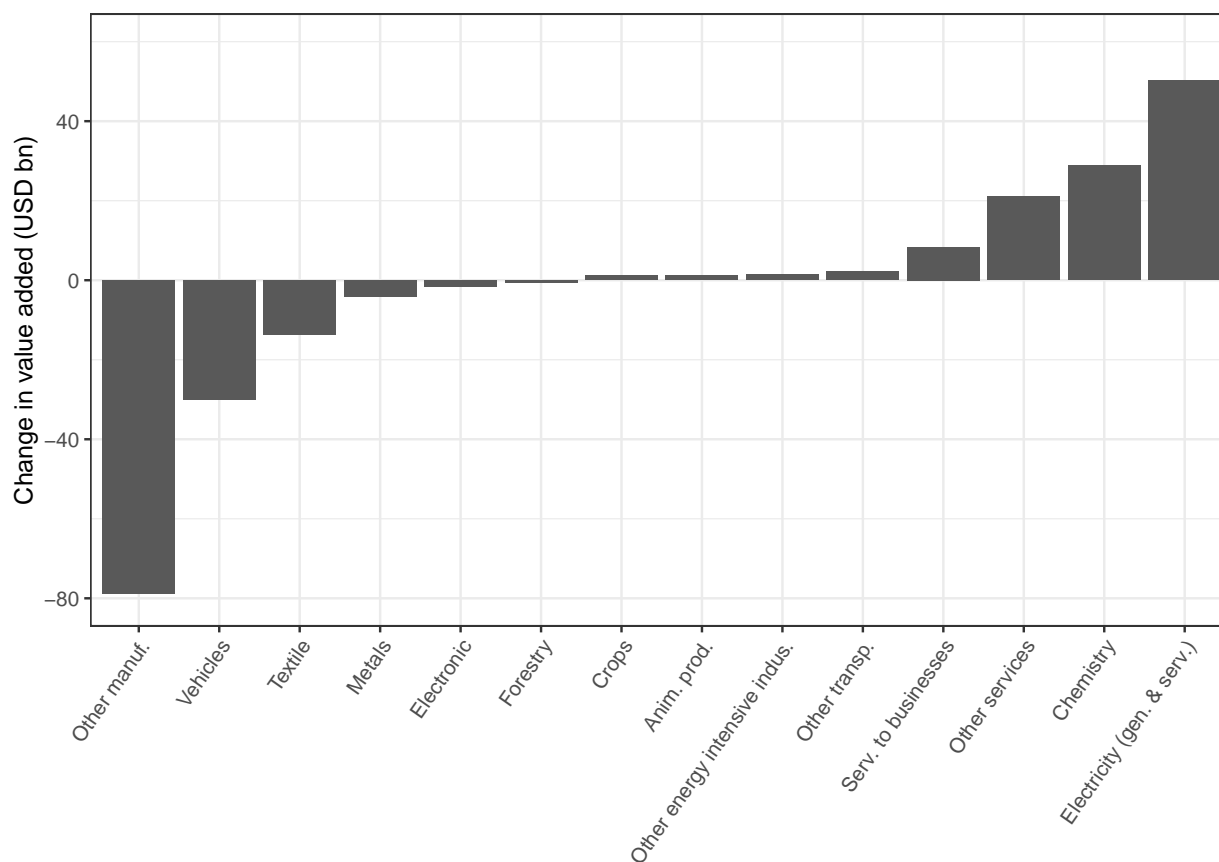


Source: simulations with MIRAGE-VA, calculations by the authors (var.> USD 50 Mn)

3. As already mentioned, the addition of the rebate magnifies the consequences of the CBAM. It subsidizes the exports of energy intensive goods. As a result, the sectors *Chemicals* and *Other energy intensive industries* now increase their value added by 1% each. 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. With a -6% loss in value added, the car industry is a good example of a sector further penalized by the larger increase in the carbon prices in the ETS, which increases the cost of intermediate consumption and raises production costs. As a consequence, downstream sectors lose market shares both on export markets and on the domestic European market. The losses in VA in the sector *Other manufactured products* now exceed USD 40 billion in 2040 (a -5% decrease).

Lastly, Figure 4 illustrates the impact of the CBAM using the exporter country as reference for emissions. The losses in value added in downstream sectors are magnified, as exemplified by other manufacturing industries (-9%) and the car industry (-10%). In contrast, chemicals are now enormously benefiting from the CBAM ($+11\%$), as opposed to scenario 1. This comparison illustrates the arbitrage to be made between restoring the level playing field upstream, and deteriorating the

Figure 4: Impact of the CBAM based on the emissions by the exporters on sectoral value added (vs baseline, in 2040)



Source: simulations with MIRAGE-VA, calculations by the authors (var. > USD 50 Mn)

level plying field downstream.

It is now worth focusing on the environmental impact of the CBAM, using the reduction in EU GHG *leakages* as a metric of the efficiency of the instrument. European leakages result from the increase in GHG emissions in unconstrained countries following the implementation of the European climate policy. Practically, we compute leakages as the difference in the emissions occurring in unconstrained countries under the scenario of interest (with the CBAM in place) and under a scenario in which the EU does not implement any climate policy, everything else being equal (in particular, the implementation of carbon policies in the countries that have taken unconditional commitments under the Paris Agreement and implemented as of 2020 a carbon pricing at the national level).³⁸

The implementation of the European NDC, *without* the CBAM, would produce leakages amounting to 30 Gt CO₂eq (*cumulated* emissions over the period from 2023 to 2040). The leakages correspond to 54% of the overall reduction in EU's GHG emissions obtained thanks to the *Green*

³⁸In our modelling framework, we account for both direct and indirect leakages but cannot directly distinguish between these two kinds of leakage.

Table 3: Focus on the environmental impact of the CBAM

	Ref. (Gt CO ₂ eq)	S1 (%)	S2 (%)	S3 (%)	S4 (%)
Global GHG emiss.	1422.7	-0.6	-0.7	-0.7	-1.0
EU leakage	30.0	-30.0	-32.5	-31.1	-45.2
ETS	16.0	-51.9	-56.3	-54.8	-77.6
Non ETS	14.0	-5.0	-5.5	-4.1	-8.2

Notes: cumulated emissions over the period 2023 - 2040. Column *Ref.* reports the value in the reference scenario. Columns *S1* to *S4* report relative changes with respect to the reference scenario. Scenarios *S1* to *S4* correspond, respectively, to: CBAM, CBAM including indirect emissions, CBAM complemented by a rebate for EU exporters, CBAM based on the emission intensity of the exporting country.
Source: MIRAGE-VA, calculations by the authors.

Deal: in other words, the leakage *intensity* amounts to 54% in our baseline. The compensation mechanism succeeds in reducing this leakage caused by the implementation of the new ambition of the EU with the Green Deal. In its simpler form (scenario 1), leakages decrease by around one third (-30%), as shown in Table 3, reducing also the leakage *intensity*, which goes from 54% to 38%. The reduction is the highest when the compensation is based on the actual exporter's emissions, as expected, and reaches -45% in scenario 4. More precisely, the CBAM mainly reduces the leakages that occur in the sectors it concerns, i.e. those covered by the ETS in our simulations: from -51.9% in scenario 1 to -77.6% in scenario 4. Leakages are also slightly reduced (between -5% and -8%) in non ETS sectors as a consequence of general equilibrium effects, following the decrease in the activity in downstream sectors and in European demand.

It is important to note that, even if the reduction in EU leakages seems large in relative terms, it only has a very small impact on *global* emissions, which are those that are actually at stake to mitigate climate change. Global emissions would be reduced by -1% in the best case, in scenario 4, which corresponds to 14 Gt CO₂eq. Practically, in 27 years, the implementation of the CBAM would allow to reduce global emissions by an amount roughly equivalent to one year of emissions by China (in 2019, China produced 13.5 Gt CO₂eq), or 3 years of emissions by the EU, at their 2019 level. The small relative size in the reduction of global emissions achieved by the CBAM is related to the fact that the EU is presently responsible of 10% of the global emissions (and even less by 2040) only.

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 for countries having managed to enforce a pricing of carbon at the national level in 2020. This is our reference. The counterfactuals consist in i) a CBAM limited to direct emissions and based on EU reference emissions; ii) augmented by indirect emissions in the electricity sector; iii) alternatively augmented by a rebate of allowances purchased on the ETS market to European exporters; iv) or alternatively augmented by an alternative choice of reference emissions, namely the exporter country's emissions. 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 2.2 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.

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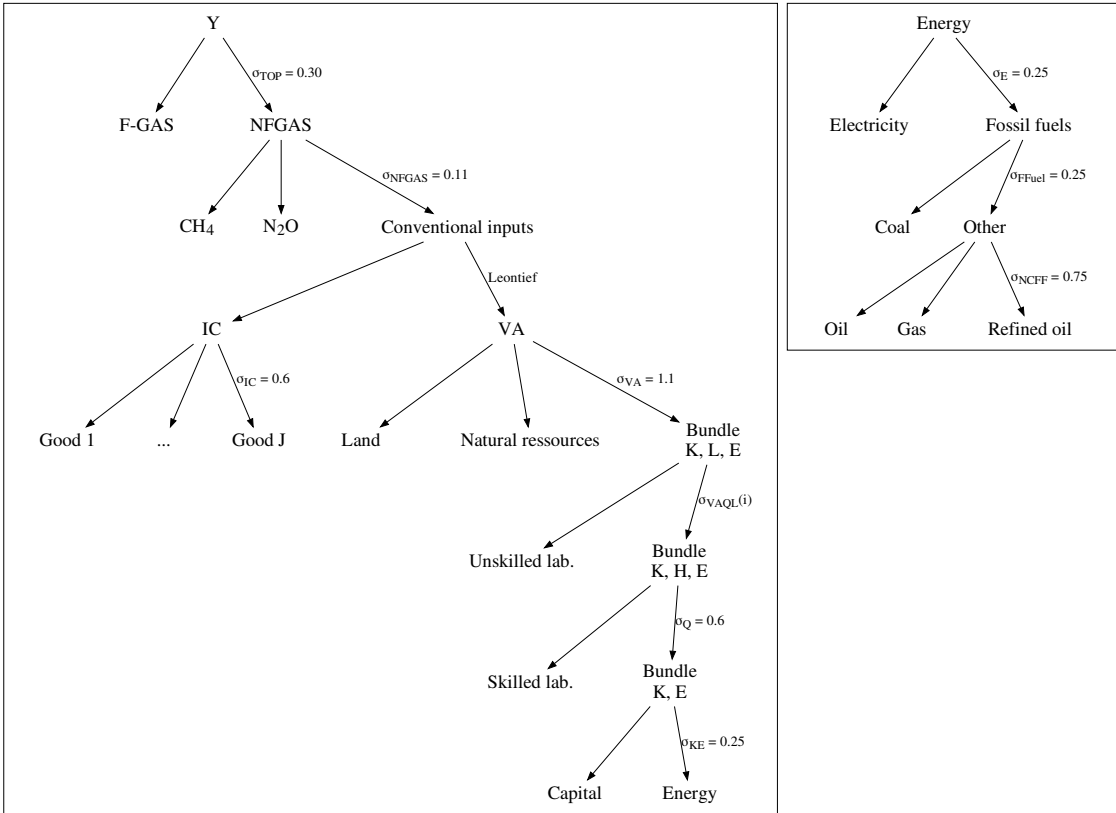
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A Appendix

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 region and sector aggregation [TO BE UPDATED](#)

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