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Comparing Scenarios for a European Carbon Border Adjustment Mechanism: Trade, FDI and Welfare Effects with a Focus on the Austrian Economy

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As the European carbon border adjustment (CBA) mechanism is high up on the European Commission's agenda and soon to be implemented, it is important to understand the economic and environmental implications of alternative designs of such a mechanism. To this end and with a view to informing the decision-making process, this study analyses and compares a series of alternative scenarios, which differ along several dimensions of a potential CBA mechanism. Two main scenarios are defined: the first one is labelled 'future ETS price scenario', which assumes a carbon price of EUR 44 and a continuation of the current practice of free allowances; the other is labelled 'IMF carbon tax scenario' and assumes a carbon price of EUR 67, which is taken from a recent publication by the IMF, and that free allowances in the industries by the CBA mechanism are abandoned. The scenario analyses rely on the multi-sector quantitative trade model by Larch and Wanner (2017) for trade and on the quantitative FDI model by Anderson et al. (2019). Overall, we find relatively small effects on EU exports, GDP and CO2 emissions. These small quantitative changes at the aggregate, however, mask larger changes at the sectoral level. As expected, the CBA mechanism is more effective when designed in a comprehensive manner, including export rebates in addition to carbon border taxes. The greater economic and environmental effectiveness of such a comprehensive design must be weighed against a heightened legal risk and fiercer opposition by developing countries which perceive the CBA mechanism as 'green protectionism' in disguise.

Keywords: Carbon border taxes, carbon tariffs, carbon leakage, climate change.
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Final Report

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Main conclusions and policy messages

- A European carbon border adjustment (CBA) mechanism is an appropriate instrument to reach the specific objectives of improving EU competitiveness and to reverse the alleged carbon leakage. The EU should therefore continue with its implementation plans for such a mechanism.

- The effects on exports and CO_2 emissions arising from the implementation of a CBA mechanism at plausible carbon prices and covering the industries currently covered by the European Emissions Trading System (ETS) must be expected to be small. Hence, the CBA mechanism by itself provides no solution to the climate challenge, but should be seen as one of many tools.

- The introduction of a CBA mechanism calls for the discontinuation of the current practice of free allowances of emission certificates within the European ETS. Free allowances undermine the effectiveness of the CBA mechanism and cause additional legal risk.

- The synchronised implementation of a CBA mechanism by major trading nations would be more effective than unilateral action by the EU. The magnifying effect of such a 'carbon club' is, however, not so large as to justify the postponement of implementing the European CBA mechanism.

- The CBA mechanism is more effective when designed in a comprehensive manner, including a carbon border tax and export rebates. The greater economic and environmental effectiveness of such a comprehensive design must be weighed against a heightened legal risk and fiercer opposition by developing countries which perceive the CBA mechanism as 'green protectionism' in disguise.

CONTENTS

TABLES AND FIGURES

Appendix

LIST OF ABBREVIATIONS

ASCM	Agreement on Subsidies and Countervailing Measures
BAT	Best available technology
CBA	Carbon border adjustment
CBT	Carbon border tax
CDM	Clean development mechanism
CGE	Computable general equilibrium
CO_2	carbon dioxide
EEX	European Energy Exchange
EFTA	European Free Trade Association
EGD	European Green Deal
EITE	Energy-intensive and trade-intensive (sectors)
ETS	Emissions Trading System
EU	European Union
EUA	European Union Allowance
FDI	Foreign direct investment
GATT	General Agreement on Tariffs and Trade
GDP	Gross domestic product
GHG	Greenhouse gases
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
JI	Joint implementation
MFN	Most-favoured nation
MW	Megawatt
NAP	National allocation plan
OBA	Output-based allocation
PE	Partial equilibrium
UNEP	United Nations Environmental Programme
WHO	World Health Organisation
WIOD	World Input-Output Database
WTO	World Trade Organisation

1. Introduction

In December 2019 the incoming European Commission announced the European Green Deal (EGD), which aims to make the EU a climate-neutral, circular economy. One of the most progressive (and concrete) elements in the EGD is the introduction of a carbon border adjustment (CBA) mechanism (European Commission, 2019).[1] The CBA mechanism constitutes a supplementary measure to the European Emissions Trading System (ETS), the EU's internal carbon pricing system introduced in 2005. The European ETS, in turn, was implemented to reduce CO_2 and other greenhouse gas emissions and to help to achieve the emissions reduction target the EU committed to under the Paris Agreement. The EU's emission reduction target is set at 40% by 2030 (compared with levels in 1990), while internally EU member states agreed to target a 55% reduction as part of the EGD.[2]

From an economic perspective, the European ETS is an instrument designed to correct the negative external effects associated with CO_2 emissions from power generation and industrial production. In view of the global dimension of the issue, the ideal solution would be to set a price for CO_2 emissions (or greenhouse gas emissions more generally) at a global level. In the absence of any global carbon pricing, the EU has resorted to unilateral action, implementing the European ETS in 2005. Although economically and ecologically sound, the European ETS (as an EU-internal carbon pricing mechanism) can address the market failure within the European Single Market, but creates distortions in trade with third countries that do not have a comparable carbon pricing system in place. The fact that EU producers bear the cost of the EU-internal carbon pricing while foreign producers remain unaffected may result in EU producers losing international competitiveness in emission-intensive industries. Associated with this distortion in international competition is a phenomenon known as 'carbon leakage'. Carbon leakage describes a situation where production takes place in other countries even if the EU industry could produce at lower costs. It also includes instances where companies move production capacities outside their jurisdictions (Felder and Rutherford, 1993).[3] An operational definition of carbon leakage is the ratio between the increase in CO_2 emissions in foreign countries that do not adopt policies for decreasing emissions, and the decrease in CO_2 emissions in countries that do implement emission-reduction policies.

The member states have expressed serious concerns about this and the risk of carbon leakage is explicitly mentioned in the EGD, as well as in the EU's revised industrial policy strategy (European Commission, 2020a). Therefore, the EU's increasingly stringent climate policy faces a dual challenge. First, to ensure a level playing field and prevent a loss of EU competitiveness and carbon leakage in view of the additional

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1 The Commission is supposed to come up with a proposal for a CBA mechanism during 2021.

2 The intention to raise the EU's greenhouse gas emission target to 55% was announced by European Commission president Ursula von der Leyen in her State of the Union Address on 16 September 2020, (see: https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_20_1655) and was adopted by member states during the meeting of the European Council on 10-11 December 2020 (see: https://www.consilium.europa.eu/en/press/press-releases/2020/12/17/council-agrees-on-full-general-approach-on-european-climate-law-proposal/).

3 If European companies build new production facilities abroad or relocate existing facilities abroad, this results in foreign direct investment (FDI), which is why FDI, in addition to trade, is relevant in the context of carbon leakage.

costs caused by the ETS. Second, to encourage its trade and investment partners to adopt similar emission-reduction measures, thus bringing them into the 'climate club'.

This is where the CBA mechanism comes into play. A CBA mechanism potentially comprises two elements: a carbon border tax (CBT)[4], which is a tax on imports, in relation to the CO_2 emissions embodied therein (i.e. an import tariff on CO_2 that equalises the differences in carbon taxes between the exporting and importing country), and a rebate of the carbon costs borne by EU producers for their exports. A CBA mechanism would equalise the price put on the carbon content of imported products with that of EU producers. In the case of a CBA mechanism consisting only of a CBT, CO_2 costs are equalised only in the EU. In contrast, a comprehensive CBA mechanism that also includes a rebate for exports could also help to restore a level playing field in third markets. Hence, the CBA mechanism aims to reduce the existing asymmetries in CO_2 costs between the EU and third-country producers, and to incentivise stricter climate change policies beyond the EU. At the same time, a CBA mechanism forms part of the EGD and should therefore be aligned with its overall objectives.

The investigation of the quantitative effects on the Austrian, the European and the global economy of a European CBA mechanism is the cornerstone of this report. The analysis includes the effects on trade and foreign direct investment (FDI), real GDP, welfare and emissions. The results are derived from state-of-the-art estimations and comprise several scenarios that assume different design options and institutional aspects of the CBA mechanism. All scenarios will assume both basic design options for the CBA mechanism, meaning either a CBT only or a comprehensive design including also rebates for EU exporters. Additional features include the granting of free allowances, sector coverage, and the EU's underlying domestic carbon pricing mechanism that the CBA mechanism is supposed to supplement. This could be a carbon tax or a cap-and-trade system. All these design features matter as do the prevailing carbon prices upon which the CBT is calculated. Given that a European CBA system could be introduced as early as 2023, it is the right time for such a scenario analysis, the findings of which, we hope, will contribute to the policy discussion on the optimal design of a European CBA mechanism.

The remainder of this report is structured as follows. Section 2 reviews some basic economics of carbon pricing, including policy measures for neutralising unintentional consequences. Section 3 describes the current EU ETS, including institutional particularities such as free allowances granted to CO_2-intensive industries, and reviews the literature on the effects of cap-and-trade systems and CBA mechanisms. Section 4 presents the scenarios for the CBA scenarios to be quantified. These scenarios feed into the quantitative analysis in Section 5, which also discusses the results of both the trade model and the FDI model. Section 6 concludes with some reflections on the policy implications of the modelling exercise.

[4] Throughout the text the terms carbon border tax, or CBT for short, and carbon tariffs are used synonymously.

2. The economics of carbon pricing

2.1. RATIONALE FOR AND MECHANISMS OF CARBON PRICING

Externalities are one of the best-known market failures preventing the market from delivering socially optimal outcomes.[5] Although deemed to be relevant in many instances, negative externalities play a particularly prominent role in the context of climate change and environmental degradation (e.g. Stern, 2007; Weitzman, 2014; Altenburg and Rodrik, 2017). The reason is that the presence of negative environmental externalities has become all too clear in the form of global warming, deforestation, loss of biodiversity, and ocean plastic pollution. This is why Sir Nicholas Stern referred to climate change as the result of *'the greatest market failure that the world has seen'*[6.] in his Royal Economic Society Lecture in 2007, for example. Viewed through the eyes of economists, environmental degradation and man-made climate change are the result of negative external effects. External effects in turn, call for policy intervention.

Typically, external effects result from incomplete regulation. In the context of CO_2 emissions, the problem arises from an insufficiently clear definition of the property rights on the 'use of air', which includes air pollution. To correct this market distortion, it is necessary to specify the conditions under which firms are permitted to pollute the air. There are two basic mechanisms to do this. First, the competent authority can directly regulate the emission activities at different levels, also referred to as command-and-control regulation (Parry and Pizer, 2007). An extreme example would be to impose a complete ban on emissions for some industries, or the prohibition of certain technologies. An example of the latter would be the compulsory phasing out of combustion-engine cars and their gradual replacement with zero-emission vehicles, which is under discussion in various countries.[7] More often than an outright ban, additional regulation takes the form of technology and performance standards (Parry and Pizer, 2007).

The payment of a price for the right to emit greenhouse gases is an alternative to direct regulation. The pricing of emissions can take the form of a tax or the requirement to obtain certificates to emit a certain amount of $CO_{2,}$[8] so-called cap-and-trade systems. Obviously, if the emission of CO_2 is no longer cost-free and polluters must pay for their emissions, over-exploitation of the air is halted or at least reduced.[9] This is the rationale behind carbon taxes as well as cap-and-trade systems, such as the EU ETS. Both pricing systems have their advantages and drawbacks.

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5 A negative external effect arises when producers do not have to pay for the full costs that their production activities impose on society. Air pollution and its negative consequences for the environment and human health are a prime example of such a negative externality (on the production side). In the absence of any efficient carbon pricing, firms will produce more than is socially desirable because they do not consider the damage that their production-related emissions impose on society.

6 See: https://www.res.org.uk/resources-page/achieving-low-carbon-growth-for-the-world----sir-nicholas-stern-on-the-key-elements-of-a-global-deal-on-climate-change.html.

7 See for example: https://qz.com/1341155/nine-countries-say-they-will-ban-internal-combustion-engines-none-have-a-law-to-do-so/.

8 In the EU ETS, these certificates are called emission allowances or European Allowance Units (EAU).

9 In a sense, a carbon pricing mechanism transforms 'unpolluted air', previously a common-resource good, into a private good – at least for firms. The excludability (with regard to firms polluting the air) is established through a laborious monitoring, reporting and verification system of enterprises and their emissions.

Cap-and-trade system. The advantage of cap-and-trade systems (such as the EU ETS) is that there is no need to set a price for CO_2 emissions. Rather, the price is determined by demand and supply within a market mechanism, which reduces the risk of distortions arising from 'inadequate' prices. What must be determined by policy makers, though, is a predefined volume of emission certificates – so-called 'allowances' – to be issued. This is the 'cap on which the system is predicated. The 'trade' part of the EU ETS stems from the fact that allowances can be bought and sold at an exchange.

As a manifestation of the Coase theorem, this market-based mechanism should lead to (allocatively) efficient outcomes. The reason is that firms that can reduce emissions at a comparatively low cost will do so and sell their excess emission allowances. In contrast, firms for which the installation of emission-mitigating measures would come at a high cost can buy such allowances. This ensures that emissions are cut where it is least costly to do so (Altenburg and Rodrik, 2017).

Moreover, in the long term, cap-and-trade systems are more effective for achieving fixed emissions targets and hence for the common global objective for stabilising the concentration of greenhouse gases in the atmosphere because the maximum quantity of emissions is pre-determined (Parry and Pizer, 2007).

However, cap-and-trade systems present their own challenges. For example, they lead to higher uncertainty for firms' investment decisions, owing to volatile CO_2 prices. They may also result in prices that are too low, as a consequence of an oversupply of (free) allowances or of a lack of demand in times of crisis. In each of these cases, low CO_2 prices undermine the steering effect of the entire carbon pricing system.[10] Additionally, cap-and-trade systems are prone to state capture by vested interests. As polluter lobbies have a clear interest in generous caps and a free allocation of emission allowances, such systems often result in low CO_2 prices and insufficient emission reductions in comparison to policy targets (Altenburg and Rodrik, 2017). Until recently, low carbon prices were an issue also within the European ETS but prices started to increase significantly in the last quarter of 2020 and, as of June 2021, have surpassed EUR 50 per tonne of CO_2.

Carbon tax. By means of a carbon tax, policy makers set an explicit price for emissions. In general, a carbon tax is less efficient from an allocative perspective. As usual, in the context of Pigovian taxes, this is related to the fact that for setting optimum carbon taxes, the government requires complete knowledge about the size of the external effect.

On the upside, carbon taxes are less prone to political capture (Parry and Pizer, 2007; Porrini, 2019) and they are easier to implement and administer (Altenburg and Rodrik, 2017). Moreover, the 'price control' (Porrini, 2019) implicit in a carbon tax has the advantage of making the costs more predictable for firms (Altenburg and Rodrik, 2017). In general, carbon taxes also generate higher revenues for the government than a cap-and-trade system, although this need not be the case if emission allowances are auctioned off and not handed out for free (Parry and Pizer, 2007).

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10 The COVID-19-related shutdown of EU economies is a case in point. Until March 2020, the spot price of a European Union Allowance (EUA) hovered around (the already low level of) EUR 25, but by mid-April it had fallen sharply to less than EUR 16. By the beginning of September 2020, the price had recovered to around EUR 25 and from then on increased steadily and exceeded EUR 40 by the end of March 2021.

It is highly relevant to both arguments – the predictability of prices and easier administration –that many experts argue that carbon taxes are more easily aligned with a CBT in a World Trade Organisation (WTO)-consistent manner (see, for example, Krenek, 2020).

Importantly, there are various similarities between the two carbon pricing mechanisms, the most important of which is that both are tools to reduce emissions by putting a price on carbon emissions, which is uniform for any emitting activity at a given point in time (Parry and Pizer, 2007). Moreover, both have the potential of being an incentive to producers in carbon-emitting industries to invest in less polluting technologies. As both systems (if implemented properly) impose a cost on CO_2-emitting producers, the key economic implications are also similar.

2.2. CARBON PRICING IN OPEN ECONOMIES

Climate change, which is a negative externality of carbon emissions, is a global issue, meaning that the positive consequences of carbon pricing are not localised (its costs, however, are). All countries may enjoy the positive impacts of reducing global warming, and all will suffer negative consequences (although not necessarily to the same extent). This situation opens up the potential for free riding, which prevents the implementation of a globally agreed (and enforceable) carbon pricing system, which would be the first-best solution (High-Level Commission on Carbon Prices, 2007). In the absence of a global carbon price, countries, or groups of countries, are forced to resort to unilateral action. The establishment of a cap-and-trade system or a carbon tax in one country means that domestic firms face extra costs, putting them in a disadvantageous position compared with their foreign competitors. Domestic consumers turn to cheaper foreign products, which increases imports and decreases domestic production. Moreover, in their search for lower costs, domestic firms might relocate their production abroad. If this leads to increased production in more emission-intensive environments, owing to increased demand or to lower prices of fossil fuels (as less is consumed in a country with a carbon price), this could lead to globally higher carbon emissions than before. This is the well-known carbon leakage effect. Carbon leakage and loss of competitiveness are two of the main unintentional and distortive consequences of fragmented climate change policies. Whether these effects actually materialise is a disputed issue, with most economic models showing carbon leakage effects ranging between 5% and 20%, and most available ex-post assessments find little evidence of this phenomenon (Zhang, 2012). Possible explanations for this include relatively low carbon prices thus far, free allocation of emission permits, and high costs related to the relocation of production abroad. Nevertheless, higher carbon prices in the future, as well as the mere perception of carbon leakage, could still warrant a policy response in the present.

Several mechanisms are discussed to prevent market distortions resulting from carbon pricing policies. The most prominent of these is the CBA mechanism, the subject of this study. An alternatives to such a mechanism is the free allocation of emission permits to firms in cap-and-trade systems provided on the basis of historic emissions (also called ‘grandfathering’). This measure is widely used in the EU ETS. Other options include output-based allocation,[11] consumption charges on selected products, or industry-wide exemptions from carbon prices. Non-price-based measures, such as import quotas or standard-setting, could also be used.

[11] Output-based allocation (OBA) refers to allocating emission allowances based on an industry-wide benchmark. The allocation amount is based on what a company’s emissions would have been if they produced at the benchmark level (see Monjon and Quirion, 2011).

Another way to deal with distortions is through international co-operation, such as accelerated technology transfers between high- and low-income countries (e.g. Wood et al., 2020; Dröge et al., 2019; Aldy and Stavins, 2012), linking different national carbon pricing mechanisms and above all the formation of a ‘climate club’ (Nordhaus, 2015). The latter received a fair amount of attention, and the Scientific Council to the German Federal Ministry for Economic Affairs and Energy (2021) dedicated a full report to the CBA mechanism as a building block for a carbon club. The general idea of a carbon club is to prevent free riding by ‘outsiders’ – countries that do not introduce a domestic carbon pricing system. For this purpose, a coalition of like-minded countries that have adopted climate protection regulations impose joint tariffs against non-coalition members (the outsiders). Ideally, from the perspective of the members of the climate club, the costs imposed on the outsiders as a consequence of the tariffs are higher than the costs of a domestic carbon pricing system. This way, outsiders could be induced to join the carbon club. Nordhaus (2015) compares the use of ‘carbon duties’ (i.e. carbon adjustments) with a uniform (and higher) increase of tariffs against third countries, and considers the latter option to be less complex to implement and more transparent. However, he considers the enforcement of compliance, not the reduction of carbon leakage, as the main motivation for creating a climate club. The carbon club with border adjustments, as modelled in Section 5, therefore takes a different approach than the one recommended by Nordhaus.

2.3. ECONOMIC IMPLICATIONS OF EXTERNAL EFFECTS[12]

To provide a basis for the expected results of the modelling exercise in Section 5, this section initially analyses the implications of negative externalities for production and welfare in an open economy setting. This is followed by a discussion of the effects of potential policy reactions, notably a carbon tax and a regime comprising a carbon tax *and* a carbon border tax (CBT). All analyses are limited to the partial equilibrium effects in a particular industry. For this purpose, it is assumed that the country under investigation is a large open economy, thus an economy that can influence world prices with its actions and is involved in trade with the rest of the world. We can imagine this economy to be the EU.

The negative external effect is assumed to be global, meaning that production in the industry is causing environmental harm in the EU as well as in the rest of the world, to the same extent in both cases. More generally, we shall assume identical demand conditions in the EU and the rest of the world. The only difference between the two countries is in the firms’ production costs in the industry, which we will assume to be export industry. This implies that EU producers’ marginal costs are lower than foreign producers’ corresponding costs and that (hypothetical) autarky prices are lower in the EU than abroad.[13] As will be seen, even under these strict assumptions and in restricting the analysis to partial equilibrium effects, many results are ambiguous and therefore provide additional motivation for undertaking the modelling exercise.

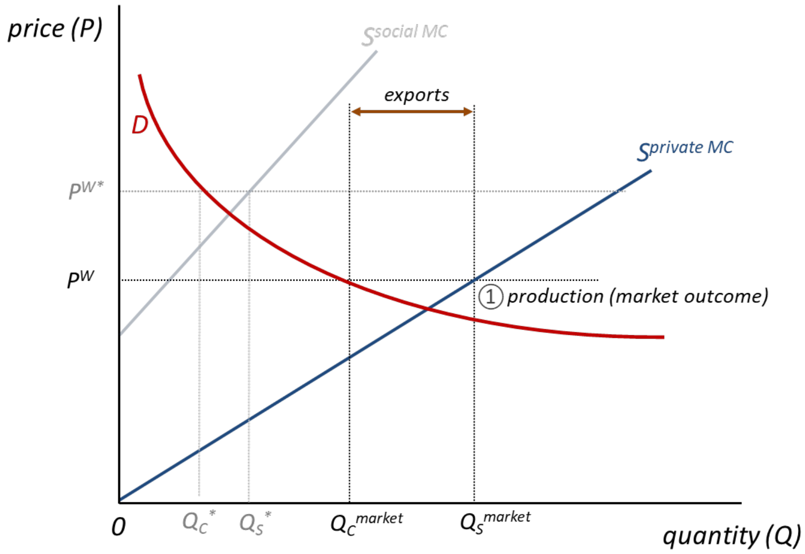
The starting point of the analysis is a market distortion caused by a negative externality on the production side in an energy-intensive industry (Figure 1). The distortion becomes evident when the market outcome (panel a) is compared with the socially optimal outcome in the industry (panel b), which is an EU export industry by assumption.

[12] The analyses in this and in the subsequent sub-section follow Stöllinger (2020).

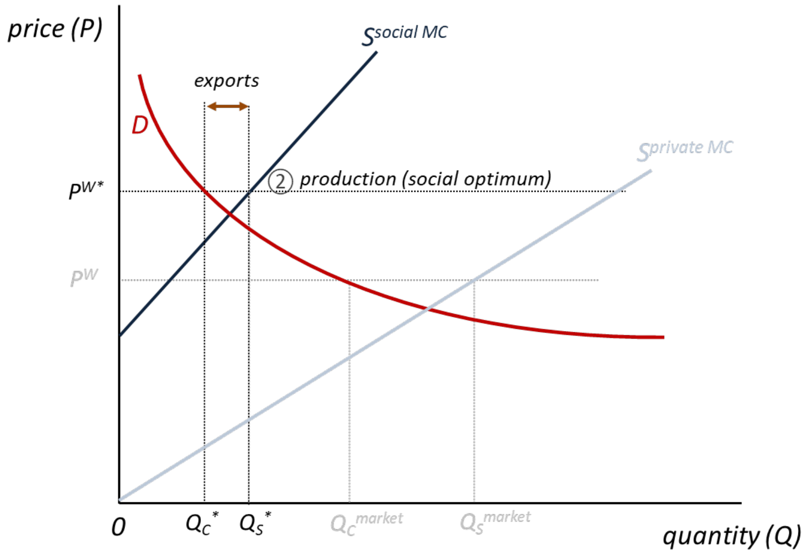
[13] In order to ensure ‘symmetric’ demand conditions, it is useful to think of the two trading partners not only as being of equal size, but also that the demand schedules feature constant elasticity.

Figure 1 / Market equilibrium and the social optimum in the presence of a negative external effect

(a) Market equilibrium in an EU export industry with a negative external effect



(b) The global social optimum in an EU export industry with a negative external effect



Note: *D* = demand; *S* = supply; *C* = consumption; *Q* = output; *MC* = marginal costs. P^W denotes the world market price under free trade; P^{W*}denotes the socially optimal world market price; Q_S^{market} and Q_C^{market} denote the EU supply and EU consumption under free market conditions; Q_S^* and Q_C^* denote the socially optimal EU production and consumption points, taking the negative externality into account.
Source: Authors' own representation.

As shown in panel (a) of Figure 1, the negative external effect in production implies that the supply curve, which reflects private marginal costs ($S^{private\ MC}$),[14] is located below the social marginal cost curve ($S^{social\ MC}$). The latter reflects the private cost curve plus the costs associated with the negative externality. In panel (a),

[14] As the supply schedule reflects marginal costs of production, the supply curve is labelled $S^{private\ MC}$, where MC stands for marginal cost.

it is depicted in pale blue to indicate that it is not relevant for the resulting free market equilibrium. The reason for this constellation of the two cost curves is that the production process imposes costs on society (i.e. the CO_2 emissions) that (profit-maximising) private firms do not have to pay for.

Assuming free trade, the equilibrium of production (Q_S^{market}) is found where marginal costs equal the world market price (P^W). Parts of EU production are sold to domestic consumers (up to the point Q_C^{market}), with the remaining quantity being exported. Obviously, the market equilibrium (Q_S^{market}) is beyond the socially optimal output (Q_S^*) produced in the EU. In this environment, EU production in the market equilibrium exceeds the optimal level because producers base their production decisions on their (private) marginal costs, ignoring the cost of the externality. Therefore, producers in the EU as well as in the rest of the world will 'oversupply' the market. EU consumption also exceeds the socially optimal level (Q_C^*) because the world market price under free trade (P^W) is too low in comparison to the socially optimal price (P^{W*}). For this reason, consumers are prepared to absorb producers' 'excess supply'.

Importantly, in both scenarios – market equilibrium and social optimum – the EU is in the position of exporter in that industry because, in the social optimum, producers in the EU *and* in the rest of the world would take the externality into account. Hence, as the externality as well as demand structures are symmetrical, the relative marginal cost structures do not change and are in favour of EU producers in both scenarios.

However, EU exports, as well as EU and global production, are unambiguously reduced by moving from the free trade equilibrium to the social optimum. This is noteworthy, as it illustrates that the environmental objective of reducing CO_2 emissions leading to a reduction of exports can be fully in line with the social planner's objective.

As the environmental externality is global in scope, the first-best solution would be a uniform carbon pricing system at a global level. In line with the objectives of this paper, the analysis proceeds with a discussion of a unilateral measure by the EU, which should be seen as part and parcel of the EGD. More precisely, two measures are considered: first, an EU-internal carbon tax, which is a tax on domestic producers; and second, a carbon border tax which is essentially a tariff on imports. As will become clear, any such unilateral measure can only be a second-best option.

2.4. THE EFFECTS OF A EUROPEAN CARBON PRICING MECHANISM

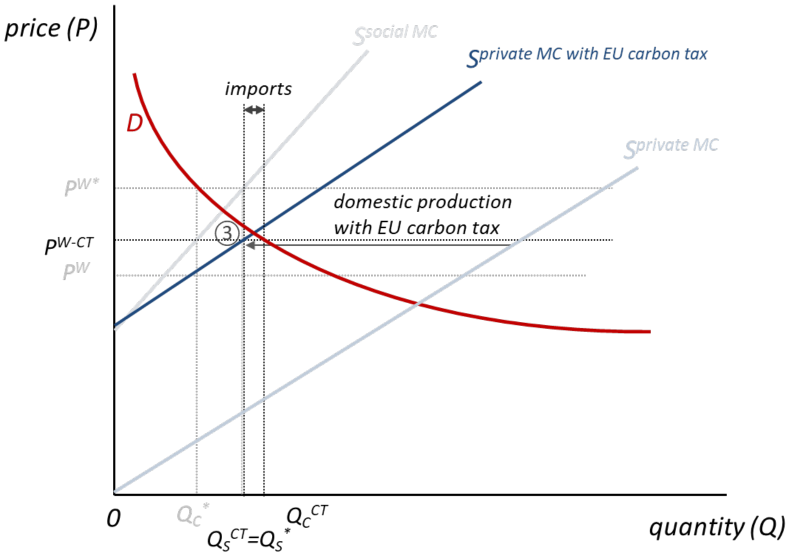
In the absence of carbon pricing at a global level, a feasible option for EU member states to make headway with their environmental objectives is the introduction of an EU-internal carbon tax (Figure 2). In this case, EU producers must bear the cost of the tax so that their supply curve shifts upwards ($S^{private\ MC\ with\ EU\ carbon\ price}$). Consequently, domestic production drops (to the level $Q_S^{EU\text{-}CT}$). At this point, EU producers' marginal cost-cum-carbon-tax equals the new world market price. This new price is above the world market price under free trade. If the amount of tax is set so that EU production equals the socially optimal level,[15] as it is assumed in Figure 2, the world market price will remain below the socially optimal price with an EU carbon tax.[16] Choosing the tax level this way is a valid option, as the externality-induced distortion – which the measure aims to remedy – is also on the production side.

15 An alternative would be to set the tax such that EU consumption equals the optimal level. In this case, the resulting price would be equal to the socially optimal price, but EU production would be severely curtailed.

16 The result of the world market price remaining below the socially optimal price hinges on the assumption that the marginal external cost increases with output. This means that an extra unit of pollution causes more harm at higher

Compared to the free trade equilibrium, the output level resulting from the introduction of the carbon tax is much lower, so carbon-intensive industry in the EU will contract – the intended impact of the carbon tax.

Figure 2 / Effects of EU carbon pricing in the presence of a negative external effect



Note: *D* = demand; *S* = supply; *C* = consumption; *Q* = output; *MC* = marginal costs; *CT* = carbon tax; *CBT* = carbon border tax. P^{W} denotes the world market price under free trade; P^{W*} denotes the socially optimal world market price; $P^{W\text{-}CT}$ denotes the world market price when the EU sets a carbon tax for EU producers; $P^{W\text{-}CBT}$ denotes the world market price when the EU levies a carbon tax on EU producers and a carbon border tax on imports into the EU; Q_S^{CT} and Q_C^{CT} denote EU supply and EU consumption if the EU sets a carbon tax for EU producers; Q_S^{CBT} and Q_C^{CBT} denote the EU supply and EU consumption if the EU levies a carbon tax on EU producers and a carbon border tax on imports into the EU. Q_S^{*} and Q_C^{*} denote the socially optimal EU production and consumption points, taking the negative externality into account.
Source: Authors' own representation.

Another directly related but unintended consequence of the carbon tax is that EU exports are lost. In the scenario depicted in Figure 2, the carbon tax will even erode EU producers' international cost competitiveness, defined as a situation where the autarky price[17] in the EU is higher than the autarky price in the rest of the world (assuming no carbon tax is introduced). In such a constellation, the EU carbon tax will turn the industry into an import-competing industry.[18] This illustrates an extreme example of the much-debated carbon leakage effect (see Section 2.2 above). Carbon leakage is indeed problematic because it results from an exacerbation of the market distortion on the production side owing to the asymmetric carbon tax that is levied only on EU producers. In other words, the loss of EU competitiveness is policy-induced and does not reflect technical productivity, resulting in even greater inefficiencies. Therefore, less productive foreign producers will expand output,[19] while more productive EU producers will curtail their

levels of output (and hence of the external effect) than at lower levels. This is a reasonable assumption in the context of environmental pollution (also see Pindyck and Rubinfeld, 2018, S.677).

17 The new autarky price in the EU takes the carbon tax into account.

18 The industry will become an import-competing industry if the required carbon tax is relatively large and the marginal cost differential between the EU and the rest of the world is small.

19 Foreign production will expand as long as the price elasticity of demand is not too high. In other words, if the contraction of the industry is sufficiently large, foreign production need not expand, or in fact, may even decline.

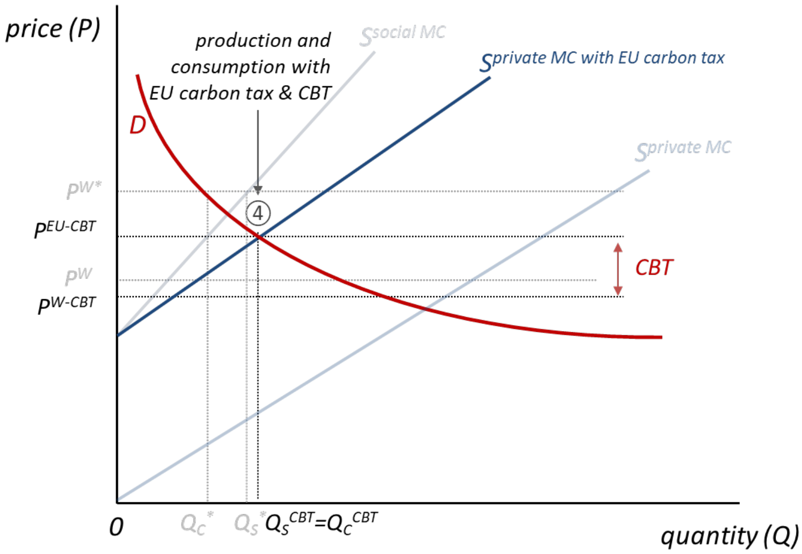
production (to Q_S^{CT}). Note that foreign production is not only too high compared to the social optimum, but also expands beyond the level of the free trade scenario.

A second problem, which is indirectly related to the phenomenon of carbon leakage, is that domestic consumption (Q_C^{CT}) remains too elevated. The reason for this is twofold. First, the world market price is too low (compared with the socially optimal price). Second, domestic and foreign consumers can buy the goods free of any carbon tax from foreign producers. This shows that the EU carbon tax is a sub-optimal policy measure to correct a market imperfection that is global in scope. While such a tax can bring EU production down to the desired level, EU and foreign consumption remain too high. It is therefore important to consider that the EU-internal carbon pricing tilts the international competition in the affected industry in favour of less productive foreign producers.

2.5. THE EFFECTS OF A EU-CARBON-TAX-CUM-CBT REGIME

One way to restore the level playing field is the introduction of a carbon border tax (CBT). The effect of the CBT is that of an import tariff: the price in the EU economy increases by the amount of the CBT.[20] This means that the CBT drives a wedge between the resulting world market price ($P^{W\text{-}CBT}$) and the price in the EU ($P^{EU\text{-}CBT}$) (Figure 3).

Figure 3 / Equilibrium in an EU-carbon-tax-cum-CBT regime



Source: Authors' own representation.

The CBT reduces EU demand, thereby bringing it closer to the social optimum. It is also able to reduce imports in the industry to nil. In this sense, the CBT is a highly effective tool. At the same time, the potential of the CBT – which remains a second-best option – to restore the EU's international competitiveness is

20 It should be noted that the CBT is only effective if the industry in question is turned into an import-competing industry as a result of the EU carbon tax. If the EU remains in the position of exporter, the CBT, being essentially an import tariff, has no effect. This limitation is, however, mainly of theoretical nature, as most industries feature intra-industry trade in reality, i.e. simultaneous imports and exports.

limited.[21] In particular, the CBT is unable to turn the industry back into an export industry without lowering the carbon tax on EU producers or the granting of a carbon tax rebate for exports. Such a rebate, while reviving EU exports, would undermine the general environmental objective of the carbon tax – and the objectives of the allowances in the context of the European ETS likewise (see also Mehling et al., 2019a). As this partial equilibrium analysis mainly serves illustrative purpose we focus on the simpler version of a CBA system without carbon rebates for exporters Thus, assuming the EU carbon tax remains in place, the best the CBT can achieve is to push EU production to the level of EU demand (at the resulting world market price). This implies that the combination of the EU carbon tax with a CBT leads to a situation with no international trade.

The reason the CBT cannot restore EU exports is that the CBT does not hit foreign sales in the rest of the world. Hence, if EU producers are unable to compete against foreign producers abroad with the EU carbon tax in place, they are also unable to do so after the introduction of the CBT. This is even more evident when the world market price declines owing to the introduction of the CBT (i.e., $P^{W\text{-}CBT}$ is lower than $P^{W\text{-}CT}$), which is the usual effect of an import tariff in the large country case.

To sum up, even if supplemented with a CBT, the unilateral carbon pricing on the part of the EU remains a second-best option. Still, it remains a useful instrument to eliminate inefficient imports in carbon-intensive industries, i.e., carbon leakage, induced by the EU carbon tax.

The bottom line is that a border adjustment mechanism makes perfect sense environmentally and economically if it is limited to a CBT levied on carbon-intensive imports. However, given that many of the effects described are ambiguous and depend on the assumptions made, the actual effects of a CBT and the more comprehensive CBA mechanism which includes in addition export rebates, need to be examined empirically, which is exactly what this study aims to do.

[21] The entire analysis assumes unilateral carbon pricing, i.e. a constellation where the EU trades with third countries without a national carbon pricing system.

3. The European Emissions Trading System and a supplementary CBA mechanism

In view of the global dimension of the issue, the ideal solution would be to set a price for CO_2 and other greenhouse gas emissions at a global level. As a global carbon pricing system is unlikely to be agreed upon soon (e.g. Cosbey et al., 2019), the EU has resorted to unilateral action, and implemented the European ETS in 2005. The EU ETS is a cap-and-trade system, which aims at internalising the CO_2 externality. Within this system, a predefined number of emission certificates – so-called ‘allowances’ – are issued. One such European Union Allowance (EUA) entitles the owner to emit one tonne of CO_2. The total amount of allowances, which is gradually reduced over time, determines the maximum amount of CO_2 to be emitted (within the sectors covered by the EU ETS). This is the ‘cap’ on which the system works. The ‘trade’ part of the EU ETS stems from the fact that allowances can be bought and sold at various energy exchanges, such as the European Energy Exchange (EEX).

The European ETS was set up in four phases and many facets of the system have changed considerably over time within these different phases, which are summarised in the next sub-section.

Initially launched as an EU mechanism, the European ETS was extended to include Iceland, Liechtenstein and Norway in 2008. In addition to the increase in geographic coverage, the coverage of facilities was also expanded over time to include more than 11,000 installations from the electricity generation sector (power stations), energy-intensive industrial plants, and airlines operating within the Single Market. As a result, about 40% of the EU's greenhouse gas emissions are currently subject to the European ETS.[22]

3.1. THE FOUR PHASES OF THE ETS

The creation of the European ETS must be viewed in connection with the 1997 Kyoto Protocol, which was the first international agreement to set legally binding emission-reduction targets (for 37 industrialised countries, including the EU member states). To meet the targets committed to under the Kyoto Protocol, the EU required policy instruments. Therefore, in 2003 the member states adopted the EU ETS Directive and in 2005 the EU system was launched. The EU ETS Handbook (European Commission, 2015) explains the history in more detail.

Phase 1 (2005-2007). The first phase acted as a pilot for phase 2, when the ETS was supposed to help the EU meet its Kyoto commitments. It laid down the groundwork by establishing an EU-wide carbon price, as well as the necessary infrastructure for verifying emissions, monitoring compliance, and trading allowances. Its scope was limited to power generation and energy-intensive industries through a list of sectors published as part of the Directive.

22 See information on the European ETS provided by the European Commission at: https://ec.europa.eu/clima/policies/ets_en

The member states were asked to provide national allocation plans (NAPs) setting national caps, the sum of which was to become the EU cap on allowances. In the absence of reliable data on emissions, the phase 1 caps were set based on estimates, which were often too high. As a result, there was an oversupply of allowances leading to consistently low allowance prices (in 2007 even at a price of zero). Importantly, almost all allowances were given to companies for free. The trading of allowances rose swiftly, from 321 million allowances traded in 2005 to 2.1 billion in 2007, according to the World Bank's annual Carbon Market Reports.

In 2004 the Linking Directive[23] allowed businesses to use certain emission-reduction units generated under the clean development mechanism (CDM) of the Kyoto Protocol and joint implementation (JI) to meet their obligations under the EU ETS.

Phase 2 (2008-2012). Phase 2 extended the ETS' reach to Iceland, Liechtenstein and Norway. It also introduced a lower cap on allowances, this time set based on actual (historical) emissions (about 6.5% lower compared with 2005). The process for developing NAPs was streamlined following delays in phase 1. Even so, the Commission rejected some of them, leading to disputes with member states such as Poland and Estonia. The proportion of freely allocated allowances also fell to 90% and penalties for non-compliance were increased significantly. In 2012 the aviation sector was included in the system, but limited to flights with origin and destination within the EU, Norway, Iceland and Liechtenstein.

Trading volumes jumped from 3.1bn in 2008 to 6.3bn in 2009. In 2012, 7.9billion allowances were traded (worth EUR 56bn). The 2008 financial crisis led to a drop in emissions, which significantly kept down the price of carbon in the remaining years.

Phase 3 (2013-2020). The third phase represented a break with several previously established practices, and a significant increase in stringency. Owing to the disappointment with the NAP system, a single EU-wide cap on emissions was established. Its annual reduction was settled at 1.74%.

Auctioning replaced free allocation as the default option for the distribution of allowances. Nevertheless, free allocation remained prominent and covered 43% of all allowances distributed in phase 3 (European Commission, 2020b). The Commission outlined rules for the attainment of free allowances owing to the threat of carbon leakage and replaced the previous system for allocating free allowances from 'grandfathering' (basing the rates on historic emissions) with a hybrid system that takes both historic emissions and sector-based benchmarks into account. A list of sectors under threat of carbon leakage was published in 2013 and updated in 2015.[24] These sectors receive 100% of allowances for free.

Coverage was extended to additional sectors, such as transport and carbon storage, and additional emission gases. The definition of combustion was expanded to cover all fuels in installations where the rated thermal input exceeds 20 megawatts (MW). Free allowances may also be granted to new entrants or to installations in the electricity sector that attempt to modernise.

23 Directive 2004/101/EC, available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32004L0101

24 See the full carbon leakage list at: https://ec.europa.eu/clima/policies/ets/allowances/leakage_en

Since 2015 the Market Stability Reserve gathers surplus allowances with the intention of improving the system's resilience to shocks. Another reserve fund, the New Entrants Reserve, supports innovative emission-reducing technologies, having sold 300m emission allowances.

The price of EUAs rebounded significantly, from around EUR 5 per allowance up to 2018 to about EUR 25 in 2019. Owed to the COVID-19 pandemic and the announcement of more stringent environmental regulation, the EUA price has increased significantly at the end of phase 3.

Phase 4 (2021-2030). The fourth phase of the ETS started at the beginning of 2021. The legislative framework was revised in 2018 to ensure a significant contribution of the European ETS to reducing CO_2 emissions, thereby increasing the EU's chances of meeting its 2030 emission-reduction targets and its obligations under the Paris Agreement.

The cap reduction rate was increased to 2.2%. The free allowances granted to firms (installations) covered by the ETS are highly relevant for the definition of the scenarios to be estimated in this study. It was decided that free allowances would remain, but the rules for their acquisition would be stricter. A new carbon leakage list will cover the full period of phase 4. While installations marked as being at high risk on the carbon leakage list will still attain a 100% free allocation rate, those less exposed will be entitled to a maximum of 30%. This share is scheduled to be phased out between 2026 and 2030. Allocation for individual installations will be made more flexible and will be adjusted annually based on production trends. Despite these adjustments, the free allowances allocated to firms will remain significant: over 6bn allowances are expected to be allocated for free throughout phase 4.

The Market Stability Reserve will be strengthened by doubling the allowances set aside in the period between 2019 and 2023. Afterwards, the reserve volume of the Market Stability Reserve is to be limited to previous year's auction volume.

Two new funds will aim to support faster technological change and innovative technologies: the Innovation Fund and the Modernisation Fund.

With these institutional changes and the further commitment to the ecological transition, the price of CO_2 emission allowances within the ETS continued their upward trend in the first half of 2021 and reached EUR 55 at the end of June 2021, double the price prevailing only a year ago.

3.2. EMPIRICAL EVIDENCE ON COMPETITIVENESS AND CARBON LEAKAGE EFFECTS

A European CBA mechanism and the EU ETS are interlinked, with the relationship being either of a complementary or a substitutional nature. For this reason, a proper understanding of the CBA must be based upon careful examination of the EU ETS.

In principle, the European ETS should be capable of increasing welfare in Austria (as well as in other EU member states) if it is successful at remedying (at least part of) the distorting effects of the negative environmental externalities (Stöllinger, 2020). Certainly, the carbon leakage problem may reduce this positive welfare effect, but a priori there is no reason to believe that it reverses the overall welfare effect.

Nevertheless, the total effect of the European ETS is difficult to pin down quantitatively, as even the magnitudes of simulated carbon leakage effects are diverse and contradictory, while they presumably constitute only a small proportion of the European ETS's overall economic effects. Yet another difficulty is posed by the fact that, in practice, little to no carbon leakage has been observed (see Zhang, 2012).

The ETS has proven to be effective at reducing production-based emissions, although additional EU policies and market factors could also play a strong role. Between 2005 and 2018 emissions in sectors covered by the ETS declined by 29%. At this rate, however, the reduction is not likely to reach the initial target of 43% by 2030 according to the European Environment Agency (2019). Moreover, EU’s new emission reduction target of 55% requires a larger reduction in ETS-based emissions, estimated by Zaklan et al. (2021) to be about 57%.

Although the ETS has lowered emissions produced within the EU, this does not automatically mean that a reduction of emissions was also achieved at a global level, as the EU’s reduction could have happened on account of an increased level of emissions embodied in imported products (and lower domestic production). Most studies dealing with this issue have focused on the first two phases of the ETS, marked by low prices of carbon and disrupted by the 2008 economic crisis.

Verde (2020) reviews econometric studies on the impact of the ETS on firms’ competitiveness (measured in terms of output, profits, or stock returns). Most of this empirical literature shows no evidence of negative effects on competitiveness (e.g. Zhang, 2012; Arlinghaus, 2015). What is more, Dechezleprêtre and Sato (2017) show that the ETS has fostered innovation in the EU. Possible explanations for the non-significant impact on firms’ competitiveness include the overwhelmingly large share of free allocations in the first two phases of the ETS, over-allocations, the small share that energy costs represent in total production costs, and the ability of companies to pass-through costs to consumers (Joletrau and Sommerfeld, 2018).

While ex-ante models usually predict significant carbon leakage rates[25] due to the ETS, there is also little ex-post evidence of the ETS leading to carbon leakage (see Zhang, 2012 for a comparison). Dechezleprêtre et al. (2019) use a large sample of firm-level data to investigate the extent of carbon leakage happening inside multinational firms covered by the ETS in the years 2007-2014. They find no evidence of carbon leakage. Taking a broader perspective, Naegele and Zaklan (2019) aim to identify carbon leakage effects in manufacturing sectors using a structural gravity model but find no evidence of such effects either. In an earlier study, Chan et al. (2013) are also unable to identify any leakage effects in a study covering the power-generation, cement, steel and iron sectors. Similar conclusions are derived from a study by the Partnership for Market Readiness (2015), an association connected to the World Bank. Kuusi et al. (2020), however, argue that the carbon intensity of European imports increased more than that of exports as the ETS moved from Phase 2 to Phase 3 and estimate a 20% leakage rate with a gravity equation.

As carbon leakage could also be reflected in the outflow of foreign direct investment (FDI) to establish production capacities abroad, changes in FDI flows could point to so-called investment leakage. Koch and Mama (2019) analyse German multinationals covered by the ETS in the period between 1999 and 2013. Although they find no statistically significant effects of the ETS on outbound FDI rates, they do report a growing number of foreign affiliates and high increases in outbound FDI for a small subset of firms. Using

[25] Estimates of carbon leakage rates: most coming from computable general equilibrium (CGE) models are usually modest, and range between 2% and 20% (Larch and Wanner, 2017), although there could be considerable heterogeneity between sectors (e.g. Fischer and Fox, 2012).

a sample of Italian multinationals, Borghesi et al. (2020) find a small, yet positive effect of the ETS on the number and sales of non-EU subsidiaries.

There are numerous explanations concerning the lack of carbon leakage observed in the EU. First, Naegele and Zaklan (2018) argue that climate costs imposed by the EU ETS represent about 0.65% of the material costs for the majority of manufactured products, and thus add relatively little to total costs. Second, relocations can be costly, risky and time-consuming. Additional costs and risks include investment costs, transportation costs, currency risks, political risks and the lack of a skilled labour force (Levinson, 2010). Third, the (over)availability of free allowances, especially in the first two phases of the EU ETS, has turned the carbon pricing system into a net subsidy for most sectors. This is particularly true for phases 1 and 2. Phase 3 saw both higher prices of permits and the availability of fewer free permits. However, the number of studies concerning this later phase of the ETS is still limited (Verde, 2020). Fourth, it may be proof of Porter's hypothesis that more stringent environmental regulation does not lead to a loss of competitiveness, but rather to more innovation in low-carbon products and improved productivity (Porter and van de Linde, 1995). Fifth, the lack of carbon leakage observed could be attributable to a low overall price of emission allowances, and hence the current and future price increases could still induce carbon leakage (Zhang, 2012). Sixth, the models mentioned above attempt to isolate the leakage that is caused by the EU ETS. It could be that the EU's wider climate change policy regime could still lead to leakage (Felbermayr and Peterson, 2020). Seventh, most economic models do not account for technological changes, which, according to Zhang (2012) and Acemoglu et al. (2012), can be endogenous and incentivised through energy prices and other instruments. Therefore, European companies could have adopted less emission-intensive practices that might spill over to their trade partners or subsidiaries.

Although ex-post studies have not detected any sizeable effects of carbon leakage or a deterioration of European firms in sectors covered by the ETS so far, the EU seems determined to supplement the EU ETS with a CBA mechanism. How such a mechanism could, in theory, help to (at least partially) remedy negative consequences, should they materialise during the current or next phase of the ETS, was discussed in Section 2. The next two sub-sections review the existing empirical results of CBA measures, first in general and then specifically in a European context.

3.3. EMPIRICAL FINDINGS REGARDING THE EFFECTS OF A CBA MECHANISM

Estimating the effects of a CBA is a complex task which requires several assumptions, including key decisions on the design of the mechanism: whether to include export rebates; whether to consider potential free allowances granted; sectoral coverage; and geographic scope. Moreover, assumptions on the evolution of emission-reduction policies may be warranted as benchmarks for CBA scenario analyses. Modelling results often depend heavily on estimations of import (Armington) elasticities (Böhringer et al., 2012a; Monjon and Quirion, 2011b). The higher the Armington elasticities, the more carbon leakage can be expected, as countries are more likely to begin sourcing products from other regions quickly should an environmental levy be imposed. The role of elasticities is taken into account in our quantitative analysis by using sector-specific elasticities.

The most commonly used tool for ex-ante assessments of the CBA's introduction are computable general equilibrium (CGE) models. Böhringer et al. (2012b) summarise findings of 29 different studies based on multi-region, multi-sector CGE models and conclude that CBA mechanisms are effective at reducing carbon leakage by a third of its benchmark value (the new mean leakage rate is 8%). Note, however, that leakage reduction rates crucially depend on the size of the abating coalition and on the size of the emission-reduction target. Moreover, CBA mechanisms are shown to be effective at maintaining domestic sectors' competitiveness by reducing output losses by almost two-thirds and can reduce GDP loss caused by climate change policies by a modest mean value of 8%. CBAs have potentially large distributional effects by shifting abatement costs from abating to non-abating countries in most cases from more to less developed countries). Thus, the CBA mechanism often has a slightly positive impact on the welfare of the implementing countries, and a negative effect for all other countries (Böhringer et al., 2019; 2018; 2012a; 2012c).

These findings are generally confirmed in a meta-regression analysis of 25 empirical studies that rely mainly on CGE models and on partial equilibrium (PE) models to a lesser extent (Branger and Quirion, 2014). The study finds leakage rates with a mean value of 6% compared with a mean value of 14% in benchmark scenarios with different climate change-regulating policies and point to the broadening of sectoral coverage[26] and the inclusion of export rebates[27] as having the strongest effects on reducing leakage (-4 percentage points each). Welfare effects on unilaterally imposing countries typically vary from -1.58% to 0.02% in benchmark scenarios featuring various abating policies but no CBA mechanism, and from -0.9% to 0.4% in scenarios that do feature a CBA mechanism. Similar conclusions are drawn by Elliot et al. (2015), Mattoo et al. (2013), Zhang (2012), Böhringer et al. (2012b), Bednar-Friedl et al., (2012), Fischer and Fox (2012), and Babiker and Rutherford (2005). Burniaux et al. (2012) conclude that CBA mechanisms do not protect energy-intensive industries from output losses.

With regard to the level of global emissions, empirical studies point to a minimal impact, although the spatial distribution of emissions will change (Sakai and Barrett, 2016; Kuik and Hofkes, 2010). In partial equilibrium (PE) models, carbon leakage is usually eliminated after introducing the CBA mechanism, which is attributed to the absence of the fossil fuel price channel in such models.

Larch and Wanner (2017) use a multi-region, multi-sector structural gravity model to decompose emission changes arising from stricter emission regulation due to the Copenhagen Accord into scale, composition, and technique effects. They show that carbon tariffs can help to reduce emissions worldwide, but at the expense of trade and welfare, especially for developing countries. In their counterfactual simulating the proposed commitments of Annex 1 countries in the Copenhagen Accord, carbon leakage decreases from 13.4% to 4.1% when a CBA mechanism is introduced. This study is of particular relevance for our report, as its trade part makes use of this model framework and applies it to a unilateral CBA mechanism introduced by the EU.

Another strand of literature uses game theoretic models, which mostly confirm that a CBA mechanism may be used to incentivise environmental regulation in trade partners and can be imposed by stable coalitions (e.g. Al Khourdaije and Finus, 2020; Hecht and Peters, 2019; Helm et al., 2012).

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[26] As coverage increases to sectors outside of the energy-intensive and trade-intensive sectors (EITEs) usually included, it starts to include sectors which are much more trade-intensive (but less carbon-intensive), thereby covering a larger share of world trade (Böhringer et al., 2012a).

[27] Rebates contribute to leakage by reducing lost market shares of domestic firms in export markets.

3.4. EMPIRICAL FINDINGS REGARDING THE EUROPEAN CBA MECHANISM

The study closest to ours was carried out by Kuusi et al. (2020) and was commissioned by the Finnish government. The aim of the study is to simulate the effects of a CBA on the Finnish economy. The simulation covers two scenarios, one focused only on energy-intensive and trade-intensive sectors (EITE) sectors and a wider one covering almost all GTAP sectors. The design of the CBA is limited to a CBT on imports and does not envisage export rebates for exporters or any other policy changes (free allocation is kept). The price of carbon is estimated at EUR 25 per tonne of CO_2 and EUR 50 per tonne of CO_2 respectively, which roughly doubles the size of the effects. First, a gravity model is used to show the impact of carbon tariffs, which would decrease the value of imports to Finland by 1.8% in the wider scenario and would decline imports to the EU by 5% if indirect emissions are also included in the tariff estimation. Second, in a CGE simulation using the GTAP CGE model, Finnish imports from non-EU countries drop. This drop in intra-EU imports is partly substituted by imports from EU countries, and increased exports to EU countries with lower exports to non-EU countries. The iron and steel sector benefits most from these changes, with increased production by 4% in the CBA scenario covering all sectors. GDP impacts are negligible in the narrower scenario and slightly negative in the wider scenario (about -0.010% for Finland). Welfare increases in both scenarios, mostly owing to the terms-of-trade effect. Furthermore, the impact of a potential trade retaliation is also assessed using the NiGEM model in form of a 2% tariff on non-commodity goods imposed by the USA. In this case, European GDP decreases by 0.05% in the long run and exports decrease by 0.025%.

Boratinsky et al. (2020) use the same CGE model to assess the effects of a CBT on imports on ETS sectors, such as ferrous metals, non-ferrous minerals, and chemicals, as well as on individual member states, including the changes in GDP, imports, exports and values of production. The introduction of import tariffs ranging from 0.6% to 3% causes a slight increase in domestic consumption owing to improved terms of trade and currency appreciation, but is offset by the drop in domestic production, thus producing a small decline in GDP (-0.06%). As far as specific sectors are concerned, the largest output changes occur in the domestic production of ferrous metals (1.1%) and non-metallic minerals (1.1%).

Monjon and Quirion (2011a) simulate CBA scenarios for energy-intensive sectors in the EU and find significant output losses for steel (-5%), aluminium (-12%), and cement (around -20%). The effect on global emissions is about -1.3% compared with a no-policy scenario.

In the model outlined by Manders and Veenendaal (2008), a CBA limited to carbon tariffs is shown to have a slightly negative impact on welfare, while a comprehensive CBA mechanism including export rebates would be slightly positive. All scenarios decrease carbon leakage, ranging from 1.4 percentage points (carbon tariffs only) to 2.8 percentage points (comprehensive CBA mechanism).

The sectors most affected by the CBA mechanism are those with high carbon and trade intensity, but the indirect effects are likely to be felt in sectors as diverse as textiles and pharmaceuticals, according to BCG (2020). In this study, it is argued that a carbon tax rate of EUR 30/tonne CO_2 for domestic producers and importers could significantly cut profits in oil refining (-20%), flat-rolled steel products (-40%), and other sectors.

Rocchi et al. (2018) estimate tariff rates on the EU’s key trading partners at the product level by contrasting the estimation of tariffs based on ‘embodied’ emissions, which take foreign emission intensities into account, with ‘avoided’ emissions, based on EU emission intensities that include emissions related to imports. Both approaches take direct and indirect emissions into account. The tariffs resulting from the latter method are much lower and amount to less than 1% in more than half of the 36 sectors covered; for the former method, tariffs exceed 2% in 40% of the sectors. The authors claim that the 'avoided' emissions approach would be more compatible with the WTO rules on 'like' products and would decrease the chances of retaliation by the EU's trade partners.

In 2020 the European Parliament (2020) commissioned a briefing on the potential reaction of the EU's trading partners, with estimations ranging from welcoming (other climate-conscious countries), to potentially oppositional (China, US) to hostile (low-income countries). Potential issues including red tape and retaliation by the EU's trade partners are further discussed by Felbermayr and Peterson (2020) and Palacková (2019). Zachmann and McWilliams (2020) discuss potential foreign and domestic political issues and recommend the EU strengthens its carbon prices, improves its environmental diplomacy and uses other measures (such as direct payments for emission reductions) to incentivise the adoption of cleaner technologies in the absence of carbon leakage evidence.

The CBA mechanism is also reviewed from an EU budget perspective (Pisani-Ferry and Fuest, 2020). Transferring the revenue from a CBA directly to the EU would create new 'true resources' for the EU, following Krenek et al. (2020), who explore the issue at depth, claiming that it could serve as an ideal green instrument to fund the budget as the additional resources could be used in various ways to reduce member states' contributions, to decrease other distortionary taxes, or to fund research and innovation programmes. They estimate a EUR 25bn revenue contribution by 2030, while Boratinsky et al. (2020) show a smaller contribution of about EUR 7.5bn.

The legality of the proposed variations of a European CBA mechanism in light of WTO law is further discussed by, among others, Folfas et al. (2020); Felbermayr and Peterson (2020), Boratinsky et al. (2020), Krenek et al. (2020), Stöllinger (2020) and Borsky (2020).

4. Designs of a CBA mechanism and definition of scenarios

4.1. ISSUES IN THE DEBATE ABOUT THE DESIGN OF A EUROPEAN CBA MECHANISM

As argued above, a European CBA mechanism is a second-best solution. It is meant to correct the asymmetry that exists between prices for domestic production and imports from third countries, thereby reducing carbon leakage.

Although a carbon border tax (CBT) is not a new idea,[28] the explicit mention of a CBA mechanism in the EGD intensified the debate about its economic, legal, and environmental consequences. According to the European Commission's roadmap initiative towards such a CBA mechanism,[29] its main objective is to fight climate change by avoiding carbon leakage. The fight against carbon leakage is the key economic objective, as it aims at restoring a level playing field for EU producers in trade relations. The fight against climate change is the primary environmental objective and, although not explicitly stated, calls for a design of the CBA that further reduces CO_2 emissions. Finally, from a legal perspective, the quintessential question is how to design the CBA mechanism in a way that is compatible with the EU's obligations under the WTO rules, in particular the General Agreement on Tariffs and Trade (GATT).

The economic and environmental efficiency and effectiveness, as well as equitability, administrative requirements, and the equally important legality and political feasibility of a European CBA mechanism will depend on its design. A growing set of literature is focused on the economic and legal consequences of different design options, either on a general level (e.g., Mehling et al., 2019a; Cosbey et al., 2019; Mattoo et al. 2013; Böhringer et al., 2012b; Cosbey et al., 2012; Fischer and Fox, 2012; Kuik and Hofkes, 2010; Manders and Veendendaal, 2008) or, more recently, when discussing the design of a European CBA (Marcu et al., 2020; Monjon and Quirion, 2010). Some of the most important design choices are presented below, as well as in Table A.7 in Appendix 4.

Compliance with the EU's obligations under the WTO. The implementation of a European CBA mechanism in a WTO-consistent manner is challenging, all the more so given that as of today no country has ever implemented such a mechanism (Mehling et al., 2019b). Nevertheless, many observers argue that a transparent, carefully designed CBA has a good chance of being compatible with WTO members' obligations under the GATT (e.g., Krenek et al., 2020; Pauwelyn, 2009; 2013; Hillman, 2013; Monjon and Quirion, 2011).

[28] However, no country has yet introduced a CBA mechanism (see Lowe, 2019). For a review of literature on the CBA mechanism, see Condon and Ignaciuk (2013).

[29] The initiative was open to public discussion until 28 October 2020 and is planned to be adopted in the second quarter of 2021. See European Commission (2020d) for details.

Moreover, the WTO itself has sent positive signals. A (highly publicised) joint report with the UN Environmental Programme (UNEP) states that GATT and WTO *'rules permit, under certain conditions, the use of border tax adjustments on imported and exported products'* (WTO-UNEP, 2009, p. xix).

With respect to legal WTO compatibility, the suggestion for the design of a European CBT by Krenek (2020) seems most convincing. The author suggests that the EU ETS is best transformed into a carbon tax, as this would provide a more stable benchmark for setting the level of the CBT. Such a benchmark is important to ensure that the CBT is non-discriminatory. In GATT terminology, the CBT should be designed as *'a charge equivalent to an internal tax'*[30] according to GATT Article II(2). GATT Article III(2) stipulates that such a charge is not allowed to be levied *'in excess of those applied, directly or indirectly, to like domestic products'* (see also WTO-UNEP, 2009), highlighting the need for a transparent benchmark. This also implies that the CBT must not be levied on the specific carbon content of the imported products, but solely on the common (e.g. the EU-wide average) carbon content of a specific product – or in WTO jargon, on a specific 'tariff line'. Otherwise, if the carbon content of imports was higher than that of domestic products, the CBT would exceed the domestic carbon tax,[31] thereby becoming discriminatory.

The assessment of discriminatory measures is related to the concept of 'likeness' enshrined in the GATT's famous most-favoured nation (MFN) principle. The likeness of products is evaluated based on four principles: (i) the characteristics of the products; (ii) the end use of the products; (iii) the classification of the products in members' schedule of concessions; and (iv) consumers' tastes and habits. The fact that the production method does not feature among these criteria is more important than the criteria themselves. Therefore, it is irrelevant whether a good, for example cold rolled steel bars, is produced using 'dirty' technology that causes a lot of emissions, or whether it applies sustainable, emission-neutral technology. Within the logic of the GATT, the differently produced cold rolled steel bars would still be the same product, with the quintessential consequence that WTO members are not allowed to treat them differently. In particular, they have to be subject to the same tariff or charge.

Krenek (2020) argues further that even if a European carbon tax did not pass the test of GATT Article II(2), the EU could use GATT Article XX, which opens up the possibility of deviating from the general GATT rules in order to protect human and animal health and life, or the preservation of exhaustible resources. Yet even in this case, the measure has to be implemented in a way that does not discriminate between countries.

For these reasons, a CBT designed as a compensatory charge on imports for an EU carbon tax (to be paid by EU producers) has good chances of being WTO-compatible. In contrast, the idea of expanding the existing EU ETS to third countries (as advocated, for example, in Mehling et al. (2019b) on the grounds that it does not require new EU legislation), is unlikely to be in line with WTO rules because it would constitute a quantitative restriction.

Therefore, these legal considerations would call for transforming the current EU ETS into an outright carbon tax, upon which a carbon-tax-cum-CBT solution could be installed. Such a change of the EU's carbon pricing system is proposed not for economic reasons but from legal necessity (i.e. WTO

[30] The alternative would be to consider the CBT as a customs duty (see also Hillman, 2013).

[31] Mattoo et al. (2013) also argue that a CBT ought to be based on the carbon content of domestic production and not on the carbon content of imports, although not on legal grounds but because of the negative trade effects for developing countries.

conformity).[32] A positive side effect of the switch to a carbon tax is that it could end the ‘carbon exemptions’ in the form of free emission allowances.

Yet another complication arises when the European CBA mechanism is to include export rebates. Mehling et al. (2019b) argue that export rebates discourage emission reductions in export-oriented sectors, which undermines the environmental rationale of the CBA mechanism, and its justification under Article XX. The greater challenge for export rebates granted under a CBA mechanism may come from, however, from the Agreement on Subsidies and Countervailing Measures (ASCM), the WTO’s subsidy code. As mentioned above, the combined report by the WTO and UNEP (WTO-UNEP, 2009) argued that, under certain conditions, the use of border tax adjustments on exports, i.e., export rebates, is permissible under WTO rules, a view that is also held by Pauwelyn (2013).

Although the inclusion of export rebates in a European CBA mechanism is seen as providing additional effectiveness to the CBA mechanism, and despite the optimistic signs coming from UNEP and the WTO, the recent literature still points to additional legal risks, without a consensus on their full extent (e.g. Ismer et al., 2020). The issue is that the explicit rebate of carbon costs (arising from the ETS or a carbon tax) to EU firms for their export operations would probably qualify as a subsidy contingent ‘upon export performance’ which is the term used in the ASCM for export subsidies, which are prohibited.[33] In this context, it does not, at first glance, seem to matter much whether such export rebates would be considered to be a rebate of a direct tax or of an indirect tax, as the illustrative list of export subsidies in the ASCM prohibits both.[34] However, according to WTO-UNEP (2009) and Brown (2010), export rebates stemming from an ‘indirect tax’ (levied on products, i.e. consumption taxes) could be in accordance under the ASCM, but only if the rebated amount is not ‘in excess’ of the taxes levied on the production and distribution of like products when sold for domestic consumption. As mentioned in the context of the CBT, fulfilling this criterion will be more challenging if the CBA mechanism is part of a cap-and-trade system with a fluctuating price (Mehling et al., 2019b). In contrast, a rebate on direct taxes as a ‘direct tax’ (levied on, and paid by, producers) would be prohibited. As it is not clear into which category the CBA (or the ETS) falls, the final decision would also depend on successful argumentation before the WTO (Garicano, 2021). The study by Ismer et al. (2020) assumes a significant legal risk of export rebates and therefore argues in favour of a (relatively complicated) system of ‘climate contributions’ (model 3 in Ismer et al., 2020) which is described in more detail in the discussion of the recent design proposals.

Hence, while the details of international trade law must be left to legal scholars, it is probably fair to say that including export rebates in the CBA mechanism adds considerable legal uncertainty to the scheme. This legal uncertainty is exacerbated by two factors. First, there are no precedents of WTO members granting export rebates to compensate domestic producers for the CO_2 costs imposed on them (see also Cosbey et al., 2019). Second, in contrast to the GATT, the ASCM does not feature an environmental safeguard clause, comparable to GATT Article XX (Kuusi et al., 2020).

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32 Another way forward would be to advocate changes in the GATT’s likeness criteria. However, this is even more unlikely to happen (given that it would require the consent of all WTO members) than an agreement among member states to replace the EU ETS with a carbon tax.

33 See Article 3 of the ASCM.

34 Annex I of the ASCM, which contains an illustrative list of such export subsidies, explicitly mentions the full or partial exemption from direct taxes (item e) as well as the exemption or remission of indirect taxes (item g) as constituting export subsidies.

Free allocation of CO_2 emission allowances. As mentioned in Section 3, the free allocation of emission certificates to EITE industries heavily exposed to international competition is common practice (and will continue to be so throughout phase 4 in the European ETS). From an economic perspective, there can be no doubt that free allowances decrease the effectiveness of the CBA mechanism as they reduce the incentives for climate action. From a legal perspective, there is also disagreement on whether they are in accordance with the ASCM as they could be considered as *de facto* export subsidies (see Ismer et al., 2020). Although no objections have so far been raised, challenges to free allocation could arise if this continues to exist under the CBA mechanism (Marcu et al., 2020).

Apart from the legal questions related to the free allocation of allowances, there is also a more fundamental subject to consider. A CBA mechanism and the free allocation of allowances are alternative instruments to tackle the twin challenges of reduced EU export competitiveness and carbon leakage. Hence, the continuation of the free allowances (as was decided for phase 4 of the ETS) undermine the effectiveness of the CBA mechanism. In other words, when implementing a comprehensive CBA mechanism that includes export rebates, there is no need for free allowances within the ETS anymore as argued also in Ismer et al. (2020). Any mechanism that aims at combining 'both worlds' necessarily becomes more complicated.

In any case, the question of whether to keep or phase out free allowances will become decisive, especially as keeping free allowances in place could be interpreted as having 'double protection'. Opinions are mixed as to whether or not free allowances interfere with the CBA mechanism (e.g. Evans et al., 2020; Monjon and Quirion, 2010). The European Commission (2020c) Inception Impact Assessment accompanying the online public consultations states that a CBA mechanism would act as an 'alternative' to existing measures to combat carbon leakage. Thus, although the share of free allocation is gradually shrinking in phase 4 (see Section 3), a CBA mechanism might ultimately replace the current free allocation programme. An alternative solution is the mixture of both systems mentioned above, in which free allowances are granted to producers of energy-intensive products up until the product-specific benchmark with final consumption being charged with exactly that benchmark rate. Additional emission certificates needed by EU producers, ought to be bought within the ETS, while imports would be subject to a CBT. ***Policy mechanism.*** The way in which a CBA will be implemented is also relevant. A notable French proposal in 2016 as well as several authors (e.g., Monjon and Quirion, 2011b) envisage implementing the CBA as part of an extended ETS. On 10 March 2021 the EU Parliament expressed support for this option.[35] This would require importers to surrender allowances at the point of entry to the EU. In the case of a comprehensive CBA mechanism, European exporters would be given allowances covering their exports to non-abating countries.

Alternatively, the CBA mechanism could be installed as part of a European-wide carbon tax, which all producers selling in the EU would be required to pay, or as an import duty, similar to an excise duty. Marcu et al. (2020), Ismer et al. (2020) and Kuusi et al. (2020) review these alternative options option in more detail. In this sense, it could mimic the border adjustment mechanism of the European value-added tax (VAT) system.

Sectoral coverage. A CBA mechanism could cover all economic sectors, or, as in most proposals, be limited to energy-intensive sectors. In the EU context, this could mean all sectors covered by the ETS, or

[35] https://www.europarl.europa.eu/news/en/press-room/20210304IPR99208/meps-put-a-carbon-price-on-certain-eu-imports-to-raise-global-climate-ambition

only those that are eligible for free allowances – sectors that are usually also trade-intensive. Additionally, a distinction could be made between basic materials and complex products.

Geographic and policy-related scope. How to address carbon pricing policies in other countries is one of the decisions to be made by the EU. Normally, the carbon levies collected in other countries would be subtracted when imposing the border adjustment rate. However, owing to large differences in implementation, it is not completely clear where to draw the line. A further challenge is the treatment of countries in which only some regions or states have implemented a comparable CBA mechanism (such as Canada).

In addition, the question of low-income countries is of special importance. Economic models show that a CBA implies a redistribution of abatement costs, in the EU's case from more to less industrialised (and wealthy) countries (e.g. Böhringer et al., 2012a). Thus, low-income countries could be exempted from the scheme, or additional measures, such as technology transfers, could be put in place.

Emissions covered and calculation methods. The emissions that should be counted when determining the carbon content of a product could be based on different criteria. The calculation could be limited to direct emissions, or it could also cover indirect emissions, such as electricity used in production, or in more complex cases, also transport-related emissions. The calculation could be limited to direct emissions (scope 1), or it could also cover indirect (scope 2) emissions, such as electricity used in production, or in more complex cases, also transport-related and other 'scope 3' emissions.

Accounting for emissions created in complex, international value chains requires special consideration. Verifying all emissions embodied in a product could be costly and complex. In practice, the CBA could be limited to downstream or upstream products, to both of these, or to basic products only, which would reduce complexity.

The carbon content estimation could be done at the individual product level, which would not only be costly for firms, but also very complex. Benchmarks are more often proposed, but these could also be determined on different bases, such as on best available technology (BAT), an average of domestic producers, or the top share thereof.

Mehling and Ritz (2020) propose a voluntary individual adjustment mechanism, which would allow foreign producers to verify that their emission content is below the benchmark and thus enjoy reduced rates of carbon taxation. This would incentivise faster technological change abroad.

Use of revenues. The revenues raised via the CBA provide two options: they can be used either to increase the primary budget or, alternatively, to finance investment and innovation in new low-carbon technologies (as a form of subsidies), refunds for domestic producers (in the case of a comprehensive CBA mechanism) or transfers to low-income countries (e.g., Mehling et al., 2019b).

Institutions and administration. The implementation of the CBA mechanism could lead to the establishment of new bodies, or the expansion of the powers of existing ones. In both cases, their task would be to oversee, monitor, and enforce the new system. Proposals in this context include institutional co-operation with the World Health Organisation (WHO), or the creation of a body under the auspices of the Intergovernmental Panel on Climate Change (IPCC). Should the CBA mechanism include a certification system, this could mean the need to establish co-operation with foreign institutions or empower domestic ones.

It is very likely that a European CBA mechanism will cause additional costs for foreign companies. Their size will depend on design choices, such as methods for calculating the emission content of products. A cost-minimising approach would be likely to lead to less complexity, which, in turn, could negatively impact the performance of the system.

Design proposals in the literature. In addition to the empirical results on the effects of a European CBA mechanism, described in the previous section and the legal debate discussed above, it is also useful to consult the literature on the possible designs of such a mechanism. It is this literature that informs the construction of our CBA scenarios. Monjon and Quirion (2010) design an ETS-based CBA mechanism including export rebates of carbon costs for European producers. Exporters would be eligible for rebates for the allowances they had to surrender for products they exported. To determine the amount of allowances per tonne, imported product-specific benchmarks should be established based on the BAT standard, rather than asking importers to report their CO_2 emissions, which could prove to be cumbersome and costly. The CBA mechanism would cover only basic products, such as cement and steel. They assess the proposal to be WTO-compatible and recommend additional measures to prevent accusations of protectionism, such as distributing the receipts of the import duty to exporting countries.

Marcu et al. (2021) describe a similar scenario, denoting it as the ‘most probable’, albeit with no export rebates and product-specific benchmarks established based on the average emission intensity of standard.

A recent proposal made by an economist and member of the European Parliament (Garicano, 2021) includes an ETS-based CBA with a system of partial export rebates, gradual elimination of free allowances, and the inclusion of indirect (scope 2) emissions into the system. Instead of EU-based benchmarks, a product-based world-average carbon intensity would be used. The proposal would include all basic materials produced in ETS sectors, and thus also cover intermediate and end products, using a formula based on the weight of material inputs. These recommendations are echoed in the report covering the resolution made by the European Parliament (2021) on the introduction of the CBA mechanism.

An alternative design of the CBA mechanism is presented by Neuhoff et al. (2021), a joint publication by the Climate Friendly Materials Platform, which draws on the study by Ismer et al. (2020) that was mentioned above in the context of the WTO compatibility. As in Ismer et al. (2020), the CBA mechanism is suggested to be implemented in form of a ‘climate contribution’. More precisely, this system consists of a destination-based carbon tax that is imposed at the stage of final consumption, if and only if the product is sold in the EU jurisdiction. Hence, the difference to a CBA mechanism with build-in export rebates would be in the design: EU producers would not need emissions allowances for their output exported, where the export can be directly or indirectly, but only for domestic sales which then obviously lifts the need for export rebates. The system is suggested to be blended with free allowances for the producers of emission-intensive products which are redubbed ‘dynamic allowances’ up to the industry benchmark level of emissions for a certain product, where these benchmarks will be adjusted year-by-year as already foreseen in phase 4 of the ETS (see phase 3.1 above). This should incentivise European producers to reduce their carbon intensity. The system is argued to be less administratively demanding because of the clear benchmark rules. If a ‘mixed system’ that comprises elements of a CBA mechanism and free allowances, as advocated by Neuhoff et al. (2021), is really less complicated and easier to administer is debatable.

4.2. DEFINITION OF CBA SCENARIOS FOR THE QUANTITATIVE MODEL

The introduction of a carbon pricing regime supplementary to EU ETS measures against carbon leakage in the form of a CBA mechanism is already laid down in the EGD. The proposal for the actual design of the CBA will be revealed by the European Commission only in June 2021 (according to the schedule). Additionally, the future price of CO_2 and therefore the size of the CBA mechanism are unknown at this stage. For this reason, the modelling of the scenarios has to make various assumptions regarding certain elements of the CBA mechanism.

It is necessary to make assumptions on the design and scope of the CBA as well as CO_2 prices and other details, such as the maintenance or discontinuation of free allowances within the ETS. Fortunately, there are a number of natural benchmarks and indications from the literature that can guide the definition of the scenarios. Making use of such guidance, we define a comprehensive set of scenarios to be investigated, which differ across all the mentioned dimensions (Table 1).

Table 1 / Overview of scenarios in the quantitative analyses

underlying EU carbon pricing system	***Cap-and-trade system (EU ETS)***			***European carbon tax***		
price scenario *design*	*Current EAU price* (EUR 25)	*Expected EAU price in 4th ETS phase* (EUR 44)		*IMF proposal* (EUR 66.99)		*Stiglitz-Stern-proposal* (89.33)
(a) CBT only (b) Comprehensive CBA	*Scenario 1*	*Scenario 2*		*Scenario 3*		*Scenario 4*
Treatment of free allowances	free allowances	free allowances	no free allowances	no free allowances		no free allowances
Industry coverage	industry coverage as in ETS	industry coverage as in ETS		industry coverage as in ETS	all industries covered	all industries covered

Note: The scenarios highlighted in grey are the main scenarios.
Source: Authors' representation.

Against the backdrop of the discussions regarding a CBA mechanism's WTO compatibility, a distinction is made between such a mechanism based on the EU's current internal carbon pricing system, the EU ETS (which is a cap-and-trade system) and one that is based on a carbon border tax instead (which is assumed to replace the current EU ETS). Moreover, in both variants the mechanism may consist of a CBT-only regime or a comprehensive CBA mechanism, which the theoretical analysis suggests would make a big difference. The four scenarios all assume a different price. In addition, the scenarios also differ in terms of sector coverage of ETS/carbon tax and whether or not free allowances to firms are granted.

A first scenario assumes that the EU ETS remains in place and that the domestic carbon price equals the price of the European Union Allowance (EUA) as of autumn 2020, when it was hovering around EUR 25.[36] The second cap-and-trade scenario puts the price at EUR 44, which is the price resulting from the so-called 'MIX' scenario in a recent study by the European Commission on future CO_2 prices for the period

[36] One EUA entitles the owner to emit one tonne of CO_2. In the current phase, some allowances are still granted for free to producers in energy-intensive sectors.

up to 2030 (European Commission, 2020d). This MIX scenario assumes that the EU and its member states use a mix of regulatory measures and that the carbon price in the ETS is steered so that the 55% greenhouse gas emission target is achieved by 2030. In this MIX scenario, the CO_2 price ranges from EUR 32 to EUR 65. While we are aware that the price of one tonne of CO_2 emissions rose to above EUR 55 we still refer to the price scenario with a price of EUR 44 as the 'future price scenario'.

Coming back to this study's scenarios, the alternative scenarios (numbers 3 and 4) assume that the EU ETS is replaced with an EU-wide carbon tax for reasons of WTO compliance. To model these scenarios, we use estimates from the literature for the appropriate level of carbon tax. More precisely, the price used for scenario 3 is a recent estimate by the IMF (2019), which puts the adequate size of a carbon tax for effectively fighting global warming at USD 75 (EUR 66.99). Scenario 4 falls back on the well-known Stiglitz-Stern proposal (High-Level Commission on Carbon Prices, 2017), which calls for a carbon tax of USD 100 (EUR 89.33). Such a high price would be in the spirit of papers calling for a high global floor on carbon prices (Rey, 2021; Böhringer and Fischer, 2020)

Adding the criteria of free allowances and industry coverage to the four price scenarios results in six scenarios. For all the scenarios, a CBT-only design and a comprehensive CBA mechanism which also includes export rebates will be analysed so that 12 model results are obtained altogether. Among the six scenarios, two are chosen as the main scenarios[37] and discussed in more detail. The first of these main scenarios is price scenario 2, which sets the ETS price at EUR 44 and keeps the current ETS coverage with free allowances remaining in place. The second main scenario is price scenario 3, which uses a carbon price of EUR 66.99 as recently proposed by the IMF. As this is a scenario that assumes a switch to a CBT, the tariff equivalents are calculated under the assumption that no free allowances or other exemptions for industries covered by the carbon tax are granted.

Given that the CBA is primarily a trade instrument, all scenarios will assume that EU member states set a common carbon tariff, and where applicable also grant common carbon rebates for exports, for each industry. It is further assumed that neither the UK nor the EFTA members join the CBA system. Hence, these countries do not introduce a CBA mechanism themselves, although they will be exempted from the EU's CBA mechanism. Moreover, the potential implications of some EU member states setting more ambitious targets and imposing further carbon taxes (e.g. Sweden), withholding parts of national allowances, or requiring additional allowances for emissions (Böhringer and Fischer, 2020) cannot be considered, owing to a lack of data.

Throughout all scenarios, the implicit price of the CO_2 emissions (p^{EUA}) resulting from the EU ETS (or an EU carbon tax), is translated into a tariff rate equivalent. This approach corresponds to the 'border tax adjustment based on domestic carbon content' in Mattoo et al. (2013) and the 'avoided emissions approach' in Rocchi et al. (2018). We proceed in two steps. First, the (scenario-specific) emission price is multiplied with the volume of emissions in each EU industry that enterprises have to actually pay for. This in turn depends on the industry coverage of the CBA mechanism and the extent to which free allowances are granted. Hence, where necessary, the number of free allowances (EUA^f) is taken into account by deducting them from the emissions covered by the EU ETS/carbon tax.

[37] This selection of the main scenarios was agreed with the Austrian Ministry of Digital and Economic Affairs in the kick-off meeting that took place on 22 October 2020.

Second, the resulting ‘CO_2 emission costs’ at the industry level are divided by gross industry output (*GO*). The tariff equivalent of the implicit ‘domestic’ carbon price is assumed to define the size of the CBT (τ^{CBT}) to be imposed on imports from non-EU partners and the carbon border rebates granted for exports to third countries (xs_k^{CBR}). This is the natural way to model the CBA mechanism, as a WTO-consistent border mechanism should match the EU-internal carbon costs. Hence, the CBT on imports of industry *k* is defined as:

$$(1) \qquad \tau_k^{CBT} = \begin{cases} \frac{p^{EUA} \cdot (CO2_k - EUA_k^f)}{GO_k} & \text{, if industry } k \in \text{ EU ETS/carbon tax} \\ 0 & \text{, otherwise} \end{cases}$$

The scenarios are defined such that free allocations of emission allowances are only relevant in the case of the cap-and-trade system. As described in Section 3, free allowances continue to exist in the fourth phase of the EU ETS. In contrast, for the carbon tax systems, we assume that no such exceptions are granted, so that EUA_k^f equals zero. Therefore, apart from the different prices assumed, a key difference between a CBA mechanism with an underlying cap-and-trade system and one with an underlying carbon tax is the possibility of free allowances.

In the comprehensive CBA scenario, the rebates granted to EU firms for exports to extra-EU countries are added. Analogous to the CBT, the magnitude of these rebates is equal to the size of the internal carbon price. The carbon border rebate to exporters, which in essence constitutes an export subsidy, xs^{CBR}, is defined as:

$$(2) \qquad xs_k^{CBR} = \begin{cases} -\frac{p^{CBR} \cdot (CO2_k - EUA_k^f)}{GO_k} & \text{, if industry } k \in \text{ EU ETS/carbon tax} \\ 0 & \text{, otherwise} \end{cases}$$

Notwithstanding these methodological commonalities, the scenarios differ significantly from each other.

Table 2 shows the resulting implicit CBT and carbon border rebates for the various sectors used in the model. In addition to the above explanations, some further observations seem appropriate.

First, we calculate uniform carbon tariffs for all EU member state at detailed industry level.[38] Nevertheless, at the sector level there is some variation of the tariff/rebate across member states. This variation stems from the need of aggregating the industry-level tariffs to the ‘composite sectors’. The resulting sector-level tariffs constitute trade-weighted tariffs. In this context, Austria seems to be an ‘average’ country, with its tariff rate close to the mean or median tariff rate applied by member states. Second, the variation across sectors is sizeable, with the non-metallic minerals, metals and chemical sectors featuring the highest carbon charges. This cross-sector variation is largely in line with that used and identified in the literature, e.g., Rocchi et al. (2018) and Kuusi et al. (2020). Some differences exist, however. For example, Rocchi et al. (2018) operate with comparatively high tariffs for coke and petroleum products, while Kuusi et al. (2020) identify lower tariffs for the chemical sector.

38 These result from a correspondence between ETS sectors and World Input-Output Database (WIOD) industries. See Appendix 2 for details.

Table 2 / Implicit carbon tariff rates and export rebates, main scenarios

	Scenario 2: Future ETS price (EUR 44)					Scenario 3: IMF carbon tax (EUR 66.99)				
GTAP sector	**Austria**	**Mean**	**Med.**	**Min.**	**Max.**	**Austria**	**Mean**	**Med.**	**Min.**	**Max.**
	Implicit carbon border tariffs					*Implicit carbon border tariffs*				
Agriculture	0.0029	0.0030	0.0031	0.0019	0.0033	0.0063	0.0064	0.0066	0.0041	0.0070
Apparel	0.0013	0.0013	0.0013	0.0013	0.0013	0.0030	0.0030	0.0030	0.0030	0.0030
Chemical	0.2772	0.2058	0.1957	0.1241	0.3296	1.1429	0.8173	0.7868	0.4029	1.3791
Equipment	0.0057	0.0065	0.0063	0.0050	0.0099	0.0132	0.0162	0.0156	0.0103	0.0299
Food	0.1039	0.1039	0.1039	0.1039	0.1039	0.1982	0.1982	0.1982	0.1982	0.1982
Machinery	0.0001	0.0001	0.0001	0.0000	0.0001	0.0003	0.0003	0.0002	0.0001	0.0004
Metal	0.1628	0.1336	0.1270	0.0255	0.2147	1.7370	1.4253	1.3552	0.2712	2.2913
Mineral	0.2361	0.2389	0.2429	0.2013	0.2484	3.0612	2.8427	2.5316	2.1007	5.7857
Mining	0.0726	0.0726	0.0726	0.0726	0.0726	0.3221	0.3221	0.3221	0.3221	0.3221
Non-tradable	1.1975	1.1165	1.1845	0.3125	2.1082	2.4450	2.2796	2.4185	0.6381	4.3045
Other	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Paper	0.1010	0.0985	0.0996	0.0849	0.1054	0.9010	0.8221	0.8581	0.4079	1.0349
Service	0.0290	0.0233	0.0241	0.0021	0.0639	0.1064	0.0857	0.0885	0.0079	0.2354
Textile	0.0013	0.0013	0.0013	0.0013	0.0013	0.0030	0.0030	0.0030	0.0030	0.0030
Wood	0.0061	0.0061	0.0061	0.0061	0.0061	0.0181	0.0181	0.0181	0.0181	0.0181
	Implicit carbon border rebates					*Implicit carbon border rebates*				
Agriculture	0.0031	0.0028	0.0030	0.0005	0.0032	0.0067	0.0059	0.0065	0.0011	0.0070
Apparel	0.0013	0.0013	0.0013	0.0013	0.0013	0.0030	0.0030	0.0030	0.0030	0.0030
Chemical	0.2764	0.2106	0.1986	0.0761	0.3519	1.1456	0.8497	0.8214	0.2541	1.4817
Equipment	0.0059	0.0066	0.0059	0.0049	0.0119	0.0140	0.0169	0.0140	0.0099	0.0383
Food	0.1039	0.1039	0.1039	0.1039	0.1039	0.1982	0.1982	0.1982	0.1982	0.1982
Machinery	0.0001	0.0001	0.0001	0.0000	0.0001	0.0003	0.0003	0.0003	0.0001	0.0004
Metal	0.1651	0.1493	0.1583	0.0134	0.2462	1.7623	1.5935	1.6892	0.1418	2.6282
Mineral	0.2228	0.2267	0.2317	0.1937	0.2484	4.0998	3.7926	3.4070	2.0952	6.3772
Mining	0.0726	0.0726	0.0726	0.0726	0.0726	0.3221	0.3221	0.3221	0.3221	0.3221
Non-tradable	1.9687	0.9315	0.9597	0.0002	2.0413	4.0197	1.9021	1.9597	0.0006	4.1681
Other	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Paper	0.1030	0.1017	0.1049	0.0765	0.1082	0.9622	0.9201	1.0189	0.1534	1.1182
Service	0.0172	0.0268	0.0184	0.0021	0.1138	0.0630	0.0984	0.0677	0.0073	0.4191
Textile	0.0013	0.0013	0.0013	0.0013	0.0013	0.0030	0.0030	0.0030	0.0030	0.0030
Wood	0.0061	0.0061	0.0061	0.0061	0.0061	0.0181	0.0181	0.0181	0.0181	0.0181

Note: A value of 1 indicates a tariff/rebate of 1%. The non-tradable sector is, by definition, irrelevant for the trade part of the modelling exercise. Mean=EU simple average tariff/rebate; Median= EU median tariff/rebate; Min.=Minimum tariff/rebate found among member states; Max.=Maximum tariff/rebate found among member states. All tariffs and rebates were derived using data from 2014.
Source: Authors' own calculations.

Third, the rather important electricity, gas, steam, and air conditioning supply industry (D35), which comprises more than 80% of all combustion of fuels activities, is assigned to the non-tradable sector.[39] This sector, by definition, does not feature any exports or imports in the model, thus the high tariffs in this sector do not influence the model's results. Fourth, the tariffs/rebates in the services sector are primarily the result of the air transport industry (H51), as EU-internal flights are covered by the EU ETS. Fifth, the two main scenarios are both intermediate cases, although price scenario 2 is at the lower end of the spectrum and below the current price of CO_2 emissions in the ETS. The carbon charges are much higher in the scenarios that assume a full sector coverage, which is not the case in price scenario 2 or price

[39] For details of the WIOD industry to GTAP sector correspondences, see Appendix 2.

scenario 3. A full overview of resulting tariffs for Austria and the EU average across all scenarios and sectors is provided in Appendix 2.

All scenarios assume that only the EU imposes CBA measures. Moreover, in all scenarios, trade with the UK, all EFTA members, and Canada, New Zealand, South Korea, and Japan is exempted from the CBA mechanism, as these countries have a domestic carbon pricing mechanism in place.

For all other trading partners, the implicit carbon tariffs in equation (1) are imposed and the implicit carbon border rebates[40] in equation (2) are added to the pre-existing (bilateral) tariffs.

As will be shown in the next section, the additional features of the CBA mechanism, such as the granting of free allowances, may be at least as important as the actual size of the carbon taxes.

[40] As the carbon border rebates have a negative sign, adding them to the existing tariffs reduces trade costs.

5. Quantitative analysis and model results

5.1. KEY FEATURES OF THE MODEL

Quantifying the direct and indirect effects of the introduction of a European CBA is not an easy task. In contrast to the estimation of trade, FDI and welfare effects resulting from a free trade agreement (FTA), there is no (planned) tariff schedule that can be used for modelling. The 'size' of the carbon border tax (CBT) is unknown at this stage. For these reasons, the analysis of the quantitative effects of a European CBA mechanism will have to make even more assumptions than is normally the case in trade (and FDI) modelling.

Equipped with the tariff equivalent for the CBT, τ^{CBT}, from the previous section, a structural gravity model is employed to estimate the effects on trade flows for all EU and EFTA countries as well as major extra-EU partner countries for each industry. The trade effects are estimated using a structural gravity model that includes multilateral resistance terms[41] and emissions. There are only a few structural gravity frameworks that take emissions into account (see, for example, Aichele, 2013; Egger and Nigai, 2012, 2015; Shapiro, 2016; Shapiro and Walker, 2018). As accounting for emission effects alongside the trade and welfare effects is crucial for evaluating the effects of carbon tariffs, we use the recent framework from Larch and Wanner (2017). This model was explicitly developed to quantify the effects of carbon tariffs on trade, GDP, welfare, and carbon emissions.[42] It is a multi-sector, multi-factor structural gravity model that allows the decomposition of the emission changes into scale, composition, and technique effects, as famously introduced by Grossman and Krueger (1993) and formalised by Copeland and Taylor (1994). The model has 14 tradable sectors and one non-tradable sector and includes 128 countries. Most importantly, the model includes energy as a production factor and treats the emissions as a proportional side output. Additionally, the utility function includes multiplicative damages from CO_2 pollution following Shapiro (2016).

This framework will allow us to quantify the effects of the European CBA measures. We think it is suitable to study the implications for Austria, as Austria is well embedded within the world economy. Hence, taking into account its trade relationships in a framework with many countries seems crucial to us. Furthermore, country-specific environmental policies that specifically target global pollutants, such as CO_2 emissions, need to be seen in light of their effects on trading partners in order properly to quantify their effectiveness in terms of emission reductions. In other words, potential leakage effects need to be properly accounted for, which the suggested model framework ensures not only by incorporating trade and emissions in an integrated manner but also by using a multi-country framework featuring a very large number of countries (128). Sector differentiation enables the study of the differential impact on industries, which are also differently dependent on energy as input.

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41 Multilateral resistance terms account for the potential trade diversion effects that arise for third parties when country pairs lower their bilateral tariffs, as is the case with FTAs. Technically, they are captured by exporter-time and importer-time fixed effects and in our specification by exporter-industry-time and importer-industry-time fixed effects because our model has an industry dimension.

42 The appropriateness of this model framework to assess the impact of a European CBT is evidenced by the fact that the recent presentation (the 35th *"Außenwirtschafts-Vorlesung"*) on the issue of 'International Trade, climate policy and carbon leakage' referred exclusively to this study for the empirical results. See: https://www.fiw.ac.at/index.php?id=1278&L=1

5.2. RESULTS AND DISCUSSION

The discussion focuses on the results for the two main scenarios. These are reported for a number of EU member states, including Austria, and a selective set of third countries in Table 3. In addition, the outcomes are reported for the EU as a group, all other third countries, the EFTA members, and the world as a whole.

A first general observation is that the economic effects of the CBA measures are very small. As expected, the effects are somewhat larger for the comprehensive design of the CBA mechanism which comprises a CBT and the export rebates. Given that the CBT constitutes an at-the-border measure, relatively larger effects are found for exports than for the other economic indicators (real GDP and welfare) in most countries. This is true for both basic design options of the CBA mechanism.

5.2.1. Future ETS price scenario

The counterfactual results for exports, real GDP, welfare and CO_2 emissions for the future ETS price scenario are shown in panel (a) of Table 3.

Starting with the ‘CBT-only design’, we find that global exports decline by an estimated 0.02%, which is to say that they remain essentially the same. Given the highly emotional discussion about the protectionist touch of CBTs, this is somewhat surprising: the introduction of a European CBT will apparently not rock world trade. There are several reasons for this negligible effect. First of all, a large share of EU countries’ trade is intra-EU trade, which is not directly affected by the carbon tariffs. Second, the carbon price in this scenario is modest and free allowances continue to be granted which results in low carbon tariffs even in EITE industries, as shown in the previous section.

Table 3 / Economic and environmental effects of a CBT only and a comprehensive CBA

(a) Future ETS price scenario

country	exports	real GDP	welfare	CO_2 emissions	exports	real GDP	welfare	CO_2 emissions
	percentage change in							
	CBAM limited to carbon tariffs				CBAM including carbon tariffs and export rebates			
AUT	0.0098	0.0043	0.0044	0.0223	0.0837	0.0098	0.0099	0.0569
DEU	0.0016	0.0039	0.0040	0.0326	0.0603	0.0077	0.0079	0.0749
FRA	0.0019	0.0039	0.0040	0.0211	0.0902	0.0104	0.0106	0.0516
ITA	-0.0079	0.0046	0.0047	0.0263	0.0547	0.0089	0.0091	0.0605
POL	0.0047	0.0052	0.0052	0.0336	0.0886	0.0115	0.0116	0.0813
SVN	0.0129	0.0042	0.0042	0.0115	0.0830	0.0089	0.0090	0.0267
SWE	0.0034	0.0045	0.0047	0.0306	0.0783	0.0113	0.0115	0.0828
AUS	-0.0245	-0.0021	-0.0021	-0.0034	-0.0228	-0.0046	-0.0046	-0.0127
BRA	-0.0305	-0.0021	-0.0020	-0.0098	-0.0205	-0.0052	-0.0050	-0.0245
CHE	0.0176	0.0034	0.0035	0.0060	0.0192	0.0007	0.0009	0.0063
CHN	-0.0163	-0.0006	-0.0006	-0.0037	-0.0051	-0.0020	-0.0020	-0.0116
ETH	-0.0452	-0.0042	-0.0040	-0.0181	-0.0456	-0.0077	-0.0074	-0.0233
GBR	0.0167	0.0020	0.0021	0.0149	0.0130	0.0003	0.0005	0.0183
IND	-0.0280	-0.0018	-0.0015	-0.0132	-0.0218	-0.0046	-0.0043	-0.0287
JPN	-0.0181	-0.0009	-0.0009	-0.0068	-0.0116	-0.0026	-0.0025	-0.0163
RUS	-0.0811	-0.0056	-0.0056	-0.0446	-0.0665	-0.0101	-0.0101	-0.0686
SAU	-0.1199	-0.0073	-0.0072	-0.0262	-0.1072	-0.0135	-0.0134	-0.0574
TUR	-0.0996	-0.0091	-0.0091	-0.0473	-0.0680	-0.0169	-0.0168	-0.0743
USA	-0.0210	-0.0008	-0.0007	-0.0032	-0.0128	-0.0020	-0.0020	-0.0070
ZAF	-0.0552	-0.0051	-0.0049	-0.0110	-0.0419	-0.0102	-0.0100	-0.0246
EU	*0.0010*	*0.0045*	*0.0046*	*0.0280*	*0.0870*	*0.0109*	*0.0111*	*0.0687*
Non-EU	*-0.0302*	*-0.0015*	*-0.0015*	*-0.0121*	*-0.0252*	*-0.0038*	*-0.0037*	*-0.0232*
EFTA	*0.0137*	*0.0028*	*0.0030*	*0.0109*	*0.0140*	*-0.0004*	*-0.0002*	*0.0157*
World	*-0.0192*	*0.0000*	*0.0001*	*-0.0068*	*0.0145*	*0.0000*	*0.0001*	*-0.0111*

(b) IMF carbon tax scenario

country	exports	real GDP	welfare	CO_2 emissions	exports	real GDP	welfare	CO_2 emissions
	percentage change in							
	CBAM limited to carbon tariffs				CBAM including carbon tariffs and export rebates			
AUT	0.0666	0.0253	0.0265	0.2323	0.5888	0.0659	0.0678	0.7984
DEU	0.0192	0.0218	0.0229	0.2649	0.3674	0.0462	0.0480	0.6817
FRA	0.0253	0.0202	0.0213	0.1844	0.4903	0.0543	0.0562	0.4883
ITA	-0.0363	0.0258	0.0269	0.2451	0.3694	0.0562	0.0581	0.7892
POL	0.0331	0.0311	0.0313	0.3247	0.6165	0.0770	0.0775	1.0070
SVN	0.0887	0.0246	0.0248	0.1106	0.5939	0.0600	0.0604	0.3857
SWE	0.0225	0.0275	0.0286	0.2980	0.5243	0.0748	0.0767	0.7948
AUS	-0.1011	-0.0113	-0.0113	-0.0399	-0.0867	-0.0259	-0.0259	-0.1592
BRA	-0.1256	-0.0108	-0.0099	-0.0953	-0.0623	-0.0281	-0.0265	-0.2607
CHE	0.1106	0.0181	0.0192	0.0870	0.1279	0.0033	0.0052	0.0636
CHN	-0.0660	-0.0034	-0.0033	-0.0290	0.0183	-0.0125	-0.0124	-0.1030
ETH	-0.2240	-0.0222	-0.0207	-0.1448	-0.2180	-0.0472	-0.0447	-0.2002
GBR	0.1048	0.0101	0.0112	0.1369	0.0919	0.0018	0.0037	0.1501
IND	-0.1251	-0.0098	-0.0079	-0.1097	-0.0712	-0.0289	-0.0256	-0.2586
JPN	-0.0607	-0.0043	-0.0041	-0.0505	-0.0159	-0.0135	-0.0131	-0.1371
RUS	-0.4954	-0.0376	-0.0376	-0.3938	-0.3920	-0.0700	-0.0700	-0.6245
SAU	-0.5856	-0.0468	-0.0461	-0.2169	-0.4502	-0.1013	-0.1000	-0.5536
TUR	-0.5401	-0.0539	-0.0532	-0.4588	-0.3056	-0.1118	-0.1106	-0.8265
USA	-0.0717	-0.0032	-0.0031	-0.0258	-0.0211	-0.0093	-0.0090	-0.0640
ZAF	-0.3116	-0.0315	-0.0299	-0.1238	-0.2391	-0.0631	-0.0605	-0.3478
EU	*0.0148*	*0.0249*	*0.0259*	*0.2543*	*0.5288*	*0.0645*	*0.0662*	*0.7420*
Non-EU	*-0.1444*	*-0.0090*	*-0.0085*	*-0.1108*	*-0.1032*	*-0.0232*	*-0.0224*	*-0.2342*
EFTA	*0.0896*	*0.0127*	*0.0139*	*0.1049*	*0.0985*	*-0.0071*	*-0.0052*	*0.1098*
World	*-0.0881*	*-0.0003*	*0.0003*	*-0.0625*	*0.1204*	*-0.0007*	*0.0003*	*-0.1050*

Note: The results in panel (a) refer to price scenario 2 in Section 4; the results in panel (b) refer to price scenario 3 in Section 4. In the CBA mechanism limited to a carbon border tax, the latter is equivalent to carbon costs for EU producers. The comprehensive CBA mechanism assumes rebates for the exports of EU producers to third countries in addition which are of equal size. The number 0.06, for example, indicates a growth of the respective variable by 0.06%.
Source: Authors' own work. based on the model by Larch and Wanner (2017).

Looking at the export development of selected country groups, one finds that the decline in trade for the EU countries is essentially zero (0.001%). This minuscule result is also noteworthy, not least because it does not follow the general pattern that export effects of a CBT tend to be larger than the effects on GDP and welfare This is explained by the two opposing forces operating on EU exports.

First, domestic production – and with it exports – will increase as imports from third countries will become relatively more expensive as a result of the CBT. The effect is small as intra-EU trade and trade with EFTA partners is not directly affected by this measure. This pro-export effect for EU member states is counteracted by a general equilibrium effect that works via reduced real GDP and associated lower import demand from third countries. The net result is an almost unchanged export volume of EU countries. The above-mentioned cost imposed on third countries by the CBT is also the reason for the decline in exports in non-EU countries (0.03%). And as they are exempted from the CBT, the EFTA members' exports increase slightly (+0.01%) as a result of both trade diversion effects and higher incomes in EU member states, many of which are important trading partners.

The global real GDP and welfare effects are close to zero. Note that the difference between real GDP and welfare is that the latter also takes the negative effects of pollution on welfare into account following Shapiro (2016). For reasonable values of the social cost of carbon, however, real GDP changes and welfare lead to very similar results.[43] The GDP effects for EU countries are slightly positive (0.005%), while non-EU countries' GDP declines by 0.002%. This is in line with the study by Kuusi et al. (2020) in which almost negligible positive effects on GDP for EU members and equally small, negative effects for third countries are reported.

Examining the country-specific results, one finds some variation across member states. Exports tend to increase in member states, including Austria (+0.01%), although not universally as the example of Italy (-0.01%) in Table 3[44] illustrates. As a small open economy, the export effect in Austria is larger than the EU average. In line with exports, Austrian real GDP and welfare also increase, but these effects are again minute, amounting to less than 0.01%. It is worth mentioning that, while the real GDP effects are clearly negligible, the case of Italy shows that the relationship between trade and GDP effects is not fully mechanical: Italian exports go down, but real GDP goes up, an outcome that can be attributed to general equilibrium effects that capture a country's industry structure.

As the carbon tariffs are closely related to the European Green Deal (EGD) and one of its objectives is the reduction of carbon leakage, the effects on CO_2 emissions are of major importance. For the EU as a whole, CO_2 emissions are marginally increased (by 0.03%). This outcome for emissions is almost uniform across member states, with Latvia the sole exception.[45] The results for Austria (+0.02%) are once more in line with the EU-wide effects on emissions. This increase in the emissions, however small it may be, is in contrast with a global decline in emissions, albeit one of less than 0.01%.

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43 The social costs of carbon are set at USD 29 per metric tonne of CO_2. For a discussion and consideration of the robustness of the welfare results with respect to the social costs of carbon, see Larch and Wanner (2017).

44 The results for all EU member states are shown in Appendix A3. The appendix shows that there are other EU member states, such as Spain and Portugal, for which the export effects are negative in the main scenarios. The export results turn positive for all EU member states in the scenarios which assume carbon tariffs for all manufacturing industries.

45 See Appendix A3.

How should we assess these outcomes in view of the two main objectives of the CBA mechanism: the restoring of EU competitiveness and mitigating carbon leakage? At least at the economy-wide level, the CBA mechanism in its limited design that features only carbon tariffs, but no export rebates, is only of limited effectiveness when it comes to pushing exports. Although the effects induced by the CBT tend to be positive, they are negligible, and so very high carbon tariffs would have to be imposed to achieve noticeable effects on the export competitiveness of the EU economy. Turning to the environmental effects, they too, tend to be very small and they have the desired effect at the global level, that is, to reduce emissions.

The constellation that EU-wide emissions increase while emissions in third countries go down is to some extent ambiguous. It is not exactly in concordance with the general objectives of the EGD and the emission-reduction targets. However, this constellation could be compatible with one of the specific objectives of the European CBA mechanism, namely the reduction of carbon leakage. It is, however, difficult to derive any strong conclusions on the question of carbon leakage. Our model does not identify the leakage caused by the ETS, but uses the situation with the ETS in place as the benchmark case. Hence, the only thing we could identify is something like a 'carbon leakage reversal' effect. If carbon leakage is defined as the increase in emissions in non-EU countries, relative to the decline in emissions in the EU induced by the ETS, the opposite effect could be engineered by the CBT. Hence, the 'carbon leakage reversal' effect associated with the CBT can be defined as the ratio between the increase in emissions in the EU and the decrease in emissions in non-EU countries. Such a reversal may not seem desirable from an environmental perspective as it would imply increasing CO_2 emissions in the EU and would go against the spirit and objectives of the EGD. However, this carbon leakage reversal, overall, results in a reduction of global emissions, which is what ultimately matters for the world climate. The fact, that global CO_2 emissions are slightly reduced while global GDP remains de facto unchanged is explained by different technologies in the EU and in third countries, and potentially also by structural adjustments. Although in practice irrelevant in view of the minuscule effects obtained in this scenario, the general tendency that EU exports as well as EU emissions increase as a result of the carbon tariffs is likely to reinforce the trading partners' already existing perception (especially in emerging markets such as India) that the European CBT is a protectionist measure in (green) disguise.

Sticking to the future ETS price scenario but shifting to a comprehensive design of the CBA mechanism that includes export rebates in addition to carbon tariffs leads mainly to quantitative differences in the results, which nevertheless remain small in terms of magnitude. As before, EU exports increase (0.09%), which also translates into an increase in global exports. While non-EU countries' exports still decline (by 0.03%), this is more than compensated by the increases in exports of EU and EFTA members. This is because the export rebates act like an export subsidy for EU exporters, leading to an increase in trade. The EU's real GDP and welfare effects remain positive and driven by export developments, and are higher compared with the limited design of the CBA mechanism that excludes export rebates. This finding is in line with Branger and Quirion (2014), Böhringer et al. (2012a) and Fischer and Fox (2012), who also report larger GDP and welfare effects resulting from a comprehensive CBA mechanism including export rebates than from a slimmer version of the CBA that does not foresee such export rebates but remains limited to a CBT.

The increase in Austrian exports (0.08%) is again in line with that of the EU. Additionally, while exports increase for all EU countries, they decline for all third countries affected by the CBA measures, that is, carbon tariff and export rebates of carbon costs.

The comprehensive CBA design implies the same qualitative environmental effects as the CBA design limited to a carbon tariff but magnified by a factor of 2 to 3. For example, while EU wide emissions are estimated to increase by 0.03% under the CBT-only design, the increase amounts to 0.07% under the comprehensive design of the CBA mechanism. This is to be expected, as the export rebates granted under the comprehensive design of the CBA mechanism reduces the costs for EU exporters leading to higher production, GDP and, ceteris paribus, also more CO_2 emissions.

Also, the decline in global CO_2 emissions is slightly larger in the comprehensive design of the CBA mechanism than in the design of the CBA mechanism that is limited to a CBT, although the effect remains really small (-0.01%).

What does this mean for the relative attractiveness of the two basic design options for the CBA mechanism? In principle, both design options can help to achieve the economic objective of increasing export competitiveness, as well as the environmental objective of fighting carbon leakage. As the latter implies an increase in the CO_2 emissions in the EU, both design options also have a downside, as the increase in emissions, while being a necessary side effect of a reversal of the supposed carbon leakage, goes against the overall objectives of the EGD. Hence, there clearly is a trade-off between the specific objectives of the CBA mechanism and the EU's general environmental objectives as envisaged by the EGD. As this trade-off is, qualitatively, the same in both design options, it does not provide guidance as to the advantage of either one or the other.

What can be said, though, is that if one judges the results of the CBA mechanism against its specific objectives, the comprehensive design of the CBA mechanism that includes export rebates emerges as the preferred option. The reason is simple: because the carbon tariff leads to the desired effects, i.e. a strengthening of the EU's export competitiveness[46] and counteracting carbon leakage, and the export rebates magnify these effects, a mechanism that includes such export rebates is more attractive. Note, however, that in this reasoning legal considerations have been set aside.

A general weakness of the future ETS price scenario, under both designs, is that the carbon tariffs and export rebates, are too low to have sizeable economic and environmental impacts. The reasons for the low tariffs are partly the CO_2 price assumed, but above all the fact that the free allowances have been assumed to remain in place in this scenario. To see the impact of these factors, we turn to the second main scenario, which assumes both higher prices and a discontinuation of the free allowances.

5.2.2. Future IMF carbon tax scenario

With the CBT imposed based on a CO_2 price of EUR 67 as suggested by the IMF (2019), the effects on exports, real GDP, welfare, and emissions are larger in magnitude than in the previous scenario (panel (b) in Table 3). Importantly, the larger effects on exports, real GDP, welfare, and CO_2 emissions in the IMF

[46] In this context it should be mentioned that export competitiveness is a rather narrow definition of international competitiveness. Market attractiveness for foreign direct investments (FDI), also known as 'locational competitiveness' as well as FDI by EU firms ('outward FDI') are also relevant aspects of international competitiveness. The role of FDI is further discussed in section 5.2.4.

carbon tax scenario are driven to a greater extent by the elimination of the free allowances. This becomes clear in Appendix 3, which contains all scenarios' results, including sub-scenarios.[47]

Qualitatively, the aggregate results in Table 3 hardly change as one moves from the future ETS price scenario to the IMF carbon tax scenario. In particular, all explanations for the existing differences between the two main design options of the CBA mechanism remain valid. Quantitatively, the effects are larger by a factor of about 10 which sounds more impressive than it is. In fact, both the economic and the environmental effects remain modest.

Going through some numbers and starting again with the limited CBA mechanism which comprises only carbon border taxes, EU exports increase by 0.015%, accompanied by a 0.02% increase in real GDP. CO_2 emissions in the EU increase by 0.25%. Globally, the corresponding changes are -0.09% for exports and -0.06% for emissions.[48] The pattern that the effects are larger in magnitude for the EU than for non-EU countries identified in the ETS future price scenario is maintained in the IMF carbon tax scenario.

The effects for Austrian exports are larger (+0.07%) than for the EU on average in this scenario, which can be attributed to the industry structure, in combination with the discontinuation of free allowances which play a larger role in some industries (e.g. the minerals sector) than in others (e.g. the machinery sector). The effect on Austrian CO_2 emission (+0.23%) remains in line with the increase in EU-wide emissions. The same is true for Austrian GDP and welfare effects.

Most importantly, when comparing the limited CBA mechanism featuring a CBT with the comprehensive design of the CBA mechanism, the important result from the previous scenario that the latter is more effective in reducing global emissions (-0.11%) is maintained. Moreover, as a result of the addition of export rebates for EU producers under the comprehensive CBA design, global exports increase slightly (+0.12%). As in the future ETS price scenario, it should be noted that this increase in exports at the global level is entirely driven by the increase in EU exports (+0.53%), which benefit from the export rebates, as they act just like an export subsidy. Exports of third countries continue to decline, although interestingly by somewhat less than in the limited CBA mechanism without export rebates for EU producers.

For the comparison of the two basic designs of the CBA mechanisms – the difference being the exclusion or inclusion of export rebates – the analysis of the results emanating from the IMF carbon tax scenario confirms the conclusions from the future ETS price scenario. Both designs are suitable to support achieving the objectives of improving the EU's export competitiveness and reversing carbon leakage effects. Hence, when judged by its specific objectives, the comprehensive design of the CBA mechanism which includes export rebated for EU producers is preferable.

The additional insight from the IMF carbon tax scenario is twofold. First, the elimination of free emission allowances is as important as changes to the carbon price. More specifically, the elimination of free emission allowances is a necessary, although not a sufficient condition, for achieving noticeable economic and environmental effects from the CBA mechanism. Against this background, it is regrettable that in a

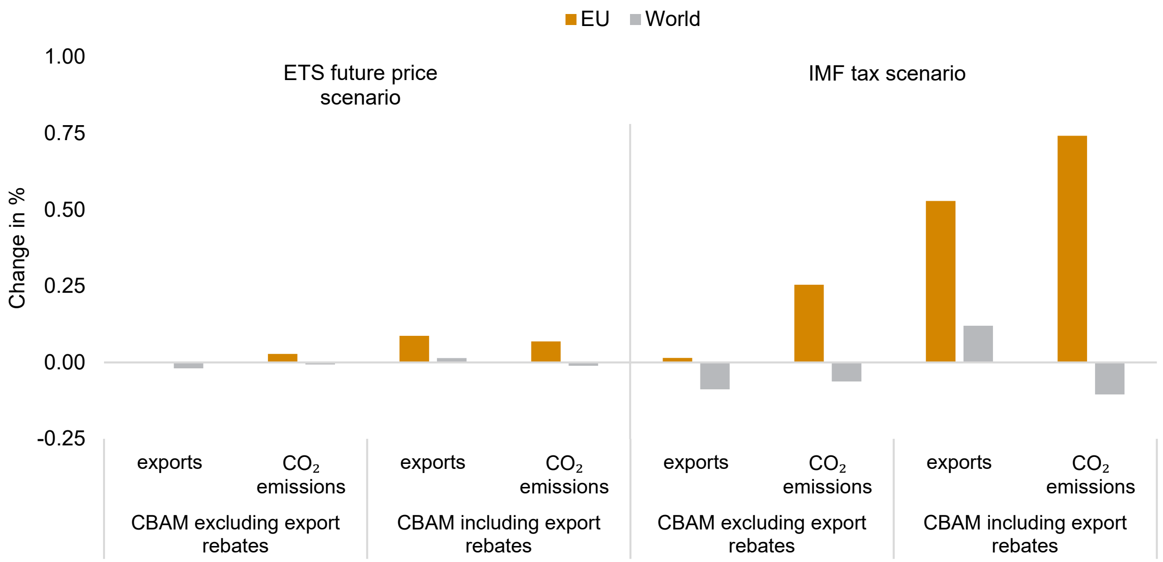
[47] It can be seen from the fact that the differences in the effects between the ETS future price scenario with and without free allowances is larger than the difference between the ETS future price scenario without free allowances and the IMF carbon tax scenario without free allowances.

[48] The effect on the global real GDP remains negligible (-0.0003%).

vote on the CBA mechanism, the European Parliament dropped its suggestion to discontinue the free allowances once the CBA mechanism is introduced.[49]

Second, even in the IMF carbon tax scenario without free allowances, the CBA mechanism does not really bite yet. This is illustrated in Figure 4, which focuses on the results for the EU and global outcomes for exports and CO_2 emissions across the two main scenarios in both design options. Exports and emissions have been chosen as they are most relevant for the CBA mechanism's main objectives. As the maximum of the vertical axis is a 1% change induced by the CBA mechanism, this shows that the aggregate results are small by any standard, which is especially true for the global outcomes. Hence, the results suggest that carbon prices ought to be quite high in order for a CBA mechanism to yield substantial results which may in turn be seen as support for a floor for carbon prices (see e.g. Ray, 2021). This is particularly true, if the cap-and-trade system is to be maintained, which – in all likelihood – is going to be the case.

Figure 4 / Main scenario results for the EU and globally, exports and CO_2 emissions



Source: Results in Table 3.

As shown in Appendix 3, much larger effects could be achieved by extending the ETS's sector coverage. For example, keeping the carbon price suggested by the IMF (as in this scenario) but extending the coverage of the ETS, and with it the coverage of the CBA mechanism, EU exports, for example, would increase by 1.9% in the comprehensive design of the CBA mechanism, while global emissions. Even in this scenario, which does not seem to be on the agenda and is even less likely than the discontinuation of the free allowances, global CO_2 emission would decline by a meagre 0.09%. This points to the fact that the European CBA mechanism by itself will not be the solution to the climate challenge, but it can be a useful part of a wider package of measure to fight climate change.

49 See: https://www.euractiv.com/section/energy-environment/news/eu-parliament-votes-to-retain-co2-quotas-for-industry/

BOX 1 / THE FORMATION OF A 'CARBON CLUB'

The quantitative results for the economic and environmental effects of a European CBA mechanism, even when applying moderately high CO_2 prices such as in the IMF proposal and including export rebates, are small. This points towards a limited leverage by the EU on global trade, production and emission outcomes, despite its status as a major trading bloc.

For this reason, an attractive alternative to a unilateral European CBA mechanism would be that the EU incentivises other, like-minded countries to form a 'climate club' (see Nordhaus, 2015). The general idea of such a climate club is that several countries that have introduced a domestic carbon pricing mechanism co-operate and set common carbon tariffs. depending on the design how to grant export rebates against 'outsiders' (countries which chose to remain outside the carbon club by not imposing domestic carbon taxes).

To investigate the effects of such a carbon club, we perform an additional simulation exercise which maintains the prices (and resulting carbon tariffs) as well as the designs of the two main scenarios but assumes that the CBA mechanism is introduced not only by the EU but by an entire carbon club. For this purpose, we assume that the UK, Switzerland, Norway, Iceland, the US, Canada, Japan, South Korea and New Zealand join the EU to form a climate club. This is a relatively large club that goes beyond the countries that have already a carbon pricing system installed. However, given the current climate debate in these countries, including the US under the Biden administration, and for the purpose of comparison, such a large club arrangement seems interesting and worth investigating. Note that by making this comparison between a unilateral EU CBA mechanism and the climate club variant of it, we do not take a position on the likelihood (or lack of likelihood) of such an arrangement.

The results of the ETS future price and the IMF tax scenarios under such a carbon club arrangement are summarised in Box Table 1 for a reduced set of countries, including both insiders and outsiders.

Starting with the global impacts, it turns out that the climate club arrangement, as expected, magnifies the effects compared with a unilateral CBA mechanism imposed by the EU. This is particularly true in the CBA design without the export rebates. Clearly, the leverage becomes larger. The reason why – especially in the case of the comprehensive CBA mechanism featuring export rebates – the global effects are not pushed up too much is that there are two main differences to the EU's unilateral CBA mechanism that work in the opposite direction. For one, as the group of carbon club members is large, the EU imposes carbon tariffs against fewer countries and (where applicable) grants export rebates to its producer in trade with fewer countries. This tends to make the effects smaller and is not negligible, because the carbon club includes major trading partners that were not exempted from the CBA measures under the EU's unilateral CBA mechanism. Meanwhile, there are now additional carbon club members that impose tariffs, and (where applicable) grant export rebates to their producers. Obviously, this tends to make the effects larger; this, on balance, is the effect that prevails and explains why the results get larger.

From a purely environmental perspective, the carbon club arrangement is certainly preferable to unilateral carbon border measures by the EU as global emissions decline more strongly throughout all scenarios. As before, this effect is considerably larger in the comprehensive CBA mechanism featuring export rebates, but so is the decline in global GDP, although this effect, in view of its size, should not be expected to cause turmoil in the world economy. Nor, however, will it solve the problem of climate change.

Box Table 1 / Economic and environmental effects under a carbon club arrangement

(a) Future ETS price scenario

	percentage change in							
country	exports	real GDP	welfare	CO_2 emissions	exports	real GDP	welfare	CO_2 emissions
	CBAM limited to carbon tariffs				CBAM including carbon tariffs and export rebates			
Insider								
EU	0.0118	0.0043	0.0045	0.0254	0.0796	0.0080	0.0083	0.0575
AUT	0.0172	0.0041	0.0043	0.0200	0.0803	0.0075	0.0078	0.0468
EFTA	0.0119	0.0033	0.0035	0.0176	0.0775	0.0053	0.0056	0.0630
GBR	0.0115	0.0038	0.0040	0.0252	0.0594	0.0058	0.0061	0.0581
USA	-0.0025	0.0025	0.0025	0.0138	0.0722	0.0048	0.0048	0.0340
JPN	-0.0219	0.0049	0.0049	0.0291	0.0450	0.0083	0.0083	0.0666
Outsider								
CHN	-0.0743	-0.0032	-0.0031	-0.0235	-0.0126	-0.0081	-0.0081	-0.0540
IND	-0.0716	-0.0048	-0.0044	-0.0282	-0.0480	-0.0111	-0.0106	-0.0613
BRA	-0.0761	-0.0054	-0.0052	-0.0200	-0.0434	-0.0118	-0.0116	-0.0509
RUS	-0.1455	-0.0103	-0.0103	-0.0643	-0.1163	-0.0175	-0.0175	-0.1064
SAU	-0.2444	-0.0134	-0.0133	-0.0368	-0.2190	-0.0226	-0.0224	-0.0885
TUR	-0.1418	-0.0134	-0.0133	-0.0593	-0.0968	-0.0241	-0.0239	-0.0954
ZAF	-0.1106	-0.0105	-0.0103	-0.0217	-0.0803	-0.0198	-0.0194	-0.0458
World	**-0.0388**	**0.0000**	**0.0001**	**-0.0114**	**0.0185**	**0.0000**	**0.0002**	**-0.0174**

(b) IMF tax scenario

	percentage change in							
country	exports	real GDP	welfare	CO_2 emissions	exports	real GDP	welfare	CO_2 emissions
	CBAM limited to carbon tariffs				CBAM including carbon tariffs and export rebates			
Insider								
EU	0.0737	0.0241	0.0258	0.2403	0.4996	0.0498	0.0525	0.6446
AUT	0.1078	0.0246	0.0265	0.2176	0.5653	0.0530	0.0559	0.6948
EFTA	0.0772	0.0147	0.0166	0.1865	0.4659	0.0253	0.0282	0.6195
GBR	0.0748	0.0199	0.0217	0.2479	0.3786	0.0351	0.0380	0.5561
USA	0.0122	0.0121	0.0124	0.1098	0.3587	0.0234	0.0239	0.2751
JPN	-0.1274	0.0271	0.0274	0.2276	0.3077	0.0521	0.0526	0.5837
Outsider								
CHN	-0.3818	-0.0187	-0.0185	-0.1863	0.0263	-0.0513	-0.0511	-0.4540
IND	-0.3219	-0.0253	-0.0222	-0.2220	-0.1587	-0.0659	-0.0608	-0.4984
BRA	-0.3141	-0.0261	-0.0245	-0.1848	-0.1305	-0.0609	-0.0584	-0.4845
RUS	-0.8218	-0.0632	-0.0632	-0.5553	-0.6375	-0.1122	-0.1122	-0.9063
SAU	-1.1534	-0.0804	-0.0792	-0.2947	-0.9299	-0.1570	-0.1550	-0.7681
TUR	-0.7319	-0.0754	-0.0742	-0.5610	-0.4145	-0.1516	-0.1497	-1.0081
ZAF	-0.5986	-0.0617	-0.0592	-0.2175	-0.4363	-0.1178	-0.1138	-0.5606
World	**-0.1873**	**-0.0005**	**0.0005**	**-0.1018**	**0.1599**	**-0.0011**	**0.0005**	**-0.1628**

Note: The results in panel (a) refer to price scenario 2 in Section 4; the results in panel (b) refer to price scenario 3 in Section 4. The number 0.07, for example, indicates a growth of the respective variable by 0.07%.
Source: Authors' own work, based on the model by Larch and Wanner (2017).

Of particular relevance in this carbon club arrangement are the distribution consequences. In this regard, the results are, to a large extent, as expected also. In general, exports, real GDP, welfare and emissions increase for the members of the carbon club (the insiders), with Japan an exception when it comes to exports in the limited CBA design that excludes export rebates. In contrast, the outsiders lose out in all the dimensions. Note, that this is exactly what a carbon club is intended for: it should impose costs on 'deviants' from global efforts to curb emissions. In the ideal case, these costs for the outsiders are larger than the costs they would face when introducing a domestic carbon pricing system (Nordhaus, 2015). An evaluation of this trade-off is, however, beyond the scope of this simulation exercise.

Note that among the outsiders, the natural resource exporters, such as Russia or Saudi Arabia, will suffer the greatest economic losses. Losses are lower for China, India and Brazil, although the pattern is the same. An exemption is China, which is expected to experience a slight gain in exports in the comprehensive CBA mechanism featuring export rebates in the IMF tax scenario. Turkey and South Africa are in an intermediate position between the natural resource exporters on the one hand and China, India and Brazil on the other, but also follow the same pattern. From all of these countries, substantial opposition to the idea of CBTs and/or export rebates is to be expected. This is also true for the unilateral CBA mechanism, but this opposition may be magnified if several WTO members join forces to form a climate club.

5.2.3. Sectoral results for Austria

The rich sector structure of the model allows an investigation of the sectors driving the aggregate changes in exports, outputs, and emissions just discussed. For this, we focus on Austria and the two main scenarios: the ETS future price scenario (Table 4) and the IMF carbon border tax scenario (Table 5).

The sectoral analysis reveals that, in essence, three sectors are most strongly affected by the carbon tariffs and export rebates, respectively. Therefore, it is these three sectors which drive the aggregate results most strongly. These sectors are chemicals, minerals and metals. This is true for exports and CO_2 emissions, as well as for output (although the non-tradables sector also plays a significant role for output). This finding holds true irrespective of the basic design option, that is, whether or not the CBA mechanism comprises export rebates. For example, in the ETS future price scenario, under the limited CBA mechanism without export rebates, exports by the chemical sector increase by 0.09%, followed by the metals and minerals sectors (+0.08% in each case). These are the industries with the highest carbon tariffs, which therefore enjoy the greatest protection from foreign competition. Note, however, that the expansion in these industries is partially offset by reductions in exports (as well as production) in most other industries.

Table 4 / Sectoral results for Austria under the future ETS price scenario

CBA mechanism limited to carbon tariffs

Sector	Exports				Output				Emissions			
	change (in %)	Contribution to % change (in p.p.)	Share in % of total change	Sector share under scenario	change (in %)	Contribution to % change (in p.p.)	Share in % of total change	Sector share under scenario	change (in %)	Contribution to % change (in p.p.)	Share in % of total change	Sector share under scenario
Total economy	0.0098	0.0098	1.0000	1.0000	0.0172	0.0172	1.0000	1.0000	0.0223	0.0223	1.0000	1.0000
Agriculture	-0.0146	-0.0003	-0.0277	0.0185	-0.0105	-0.0002	-0.0099	0.0162	-0.0267	-0.0005	-0.0218	0.0182
Mining	0.1159	0.0006	0.0597	0.0050	0.1436	0.0006	0.0363	0.0044	0.1274	0.0008	0.0349	0.0061
Food	0.0330	0.0016	0.1596	0.0472	0.0380	0.0014	0.0839	0.0381	0.0217	0.0003	0.0151	0.0154
Textiles	-0.0270	-0.0003	-0.0263	0.0095	-0.0238	-0.0002	-0.0107	0.0077	-0.0400	-0.0001	-0.0049	0.0027
Apparel	-0.0302	-0.0003	-0.0269	0.0087	-0.0280	-0.0002	-0.0112	0.0069	-0.0442	-0.0001	-0.0023	0.0012
Wood	-0.0055	-0.0001	-0.0133	0.0234	-0.0021	0.0000	-0.0024	0.0196	-0.0183	-0.0002	-0.0111	0.0135
Paper	0.0302	0.0009	0.0971	0.0315	0.0352	0.0010	0.0557	0.0272	0.0190	0.0006	0.0260	0.0305
Minerals	0.0776	0.0028	0.2848	0.0358	0.0876	0.0028	0.1607	0.0316	0.0714	0.0180	0.8089	0.2527
Chemicals	0.0893	0.0045	0.4645	0.0508	0.1015	0.0039	0.2286	0.0388	0.0853	0.0056	0.2528	0.0661
Metals	0.0811	0.0052	0.5311	0.0640	0.0909	0.0046	0.2665	0.0505	0.0746	0.0035	0.1569	0.0469
Machinery	-0.0367	-0.0040	-0.4095	0.1088	-0.0347	-0.0028	-0.1638	0.0813	-0.0509	-0.0008	-0.0379	0.0166
Equipment	-0.0082	-0.0005	-0.0501	0.0598	-0.0068	-0.0003	-0.0174	0.0443	-0.0230	-0.0001	-0.0061	0.0059
Other	-0.0484	-0.0007	-0.0704	0.0142	-0.0441	-0.0005	-0.0298	0.0116	-0.0603	0.0000	-0.0018	0.0007
Services	0.0005	0.0003	0.0272	0.5227	0.0015	0.0006	0.0324	0.3744	-0.0147	-0.0059	-0.2652	0.4017
Non-tradables					0.0265	0.0066	0.3812	0.2474	0.0103	0.0013	0.0565	0.1218

contd.

Table 4 / Contd.

Comprehensive CBA mechanism including carbon tariffs and export rebates

Sector	Exports				Output				Emissions			
	change (in %)	Contribution to % change (in p.p.)	Share in % of total change	Sector share under scenario	change (in %)	Contribution to % change (in p.p.)	Share in % of total change	Sector share under scenario	change (in %)	Contribution to % change (in p.p.)	Share in % of total change	Sector share under scenario
Total economy	0.0837	0.0837	1.0000	1.0000	0.0319	0.0319	1.0000	1.0000	0.0569	0.0569	1.0000	1.0000
Agriculture	-0.0338	-0.0006	-0.0075	0.0185	-0.0294	-0.0005	-0.0149	0.0162	-0.0591	-0.0011	-0.0189	0.0181
Mining	0.2399	0.0012	0.0144	0.0050	0.1250	0.0005	0.0170	0.0044	0.0953	0.0006	0.0103	0.0061
Food	0.1783	0.0084	0.1006	0.0473	0.0919	0.0035	0.1096	0.0381	0.0622	0.0010	0.0169	0.0154
Textiles	-0.0727	-0.0007	-0.0082	0.0095	-0.0679	-0.0005	-0.0164	0.0077	-0.0975	-0.0003	-0.0047	0.0027
Apparel	-0.0812	-0.0007	-0.0084	0.0087	-0.0782	-0.0005	-0.0169	0.0069	-0.1079	-0.0001	-0.0022	0.0012
Wood	-0.0221	-0.0005	-0.0062	0.0234	-0.0206	-0.0004	-0.0126	0.0196	-0.0503	-0.0007	-0.0120	0.0135
Paper	0.1464	0.0046	0.0550	0.0315	0.0779	0.0021	0.0665	0.0273	0.0482	0.0015	0.0259	0.0305
Minerals	0.3331	0.0119	0.1426	0.0359	0.1889	0.0060	0.1868	0.0316	0.1592	0.0402	0.7070	0.2528
Chemicals	0.8141	0.0414	0.4942	0.0512	0.4008	0.0155	0.4867	0.0389	0.3711	0.0245	0.4312	0.0663
Metals	0.4199	0.0269	0.3210	0.0642	0.2147	0.0108	0.3395	0.0506	0.1849	0.0087	0.1524	0.0469
Machinery	-0.1040	-0.0113	-0.1353	0.1087	-0.0998	-0.0081	-0.2542	0.0812	-0.1294	-0.0022	-0.0378	0.0166
Equipment	-0.0257	-0.0015	-0.0183	0.0597	-0.0309	-0.0014	-0.0429	0.0443	-0.0606	-0.0004	-0.0063	0.0059
Other	-0.1252	-0.0018	-0.0212	0.0142	-0.1158	-0.0013	-0.0423	0.0116	-0.1454	-0.0001	-0.0017	0.0007
Services	0.0124	0.0065	0.0773	0.5224	-0.0107	-0.0040	-0.1250	0.3743	-0.0403	-0.0162	-0.2849	0.4014
Non-tradables					0.0412	0.0102	0.3192	0.2474	0.0115	0.0014	0.0247	0.1218

Note: The results refer to price scenario 2 in Section 4. In the CBA mechanism limited to a CBT, the latter is equivalent to carbon costs for EU producers. The comprehensive CBA mechanism assumes rebates for the exports of EU producers to third countries in addition, which are of equal size.
Source: Authors' own work, based on the model by Larch and Wanner (2017).

Table 5 / Sectoral results for Austria under the IMF carbon tax scenario

CBA mechanism limited to a carbon tariffs

	Exports				Output				Emissions			
Sector	change (in %)	Contribution to % change (in p.p.)	Share in % of total change	Sector share under scenario	change (in %)	Contribution to % change (in p.p.)	Share in % of total change	Sector share under scenario	change (in %)	Contribution to % change (in p.p.)	Share in % of total change	Sector share under scenario
Total economy	0.0666	0.0666	1.0000	1.0000	0.1168	0.1168	1.0000	1.0000	0.2323	0.23229	1.0000	1.0000
Agriculture	-0.0819	-0.0015	-0.0228	0.0185	-0.0580	-0.0009	-0.0080	0.0162	-0.1660	-0.00302	-0.0130	0.0181
Mining	0.4199	0.0021	0.0317	0.0051	0.5450	0.0024	0.0203	0.0044	0.4364	0.00267	0.0115	0.0061
Food	0.0275	0.0013	0.0195	0.0472	0.0477	0.0018	0.0156	0.0380	-0.0604	-0.00093	-0.0040	0.0154
Textiles	-0.1740	-0.0017	-0.0248	0.0095	-0.1542	-0.0012	-0.0102	0.0077	-0.2621	-0.00072	-0.0031	0.0027
Apparel	-0.1941	-0.0017	-0.0254	0.0087	-0.1801	-0.0012	-0.0107	0.0069	-0.2879	-0.00034	-0.0015	0.0012
Wood	-0.0515	-0.0012	-0.0181	0.0233	-0.0297	-0.0006	-0.0050	0.0195	-0.1377	-0.00186	-0.0080	0.0135
Paper	0.2481	0.0078	0.1173	0.0315	0.2868	0.0078	0.0669	0.0273	0.1784	0.00545	0.0235	0.0305
Minerals	0.8544	0.0306	0.4598	0.0361	0.9842	0.0311	0.2662	0.0319	0.8751	0.22100	0.9514	0.2542
Chemicals	0.2970	0.0151	0.2267	0.0509	0.3518	0.0136	0.1168	0.0389	0.2434	0.01608	0.0692	0.0661
Metals	0.9225	0.0590	0.8867	0.0645	1.0121	0.0511	0.4378	0.0510	0.9029	0.04230	0.1821	0.0472
Machinery	-0.2333	-0.0254	-0.3815	0.1085	-0.2208	-0.0180	-0.1538	0.0811	-0.3286	-0.00546	-0.0235	0.0165
Equipment	-0.0626	-0.0037	-0.0562	0.0597	-0.0542	-0.0024	-0.0205	0.0442	-0.1621	-0.00096	-0.0041	0.0059
Other	-0.3044	-0.0043	-0.0650	0.0142	-0.2780	-0.0032	-0.0277	0.0116	-0.3857	-0.00026	-0.0011	0.0007
Services	-0.0188	-0.0099	-0.1480	0.5223	-0.0141	-0.0053	-0.0451	0.3740	-0.1221	-0.04905	-0.2112	0.4004
Non-tradables					0.1688	0.0417	0.3575	0.2475	0.0606	0.00738	0.0318	0.1217

contd.

Table 5 / Contd.

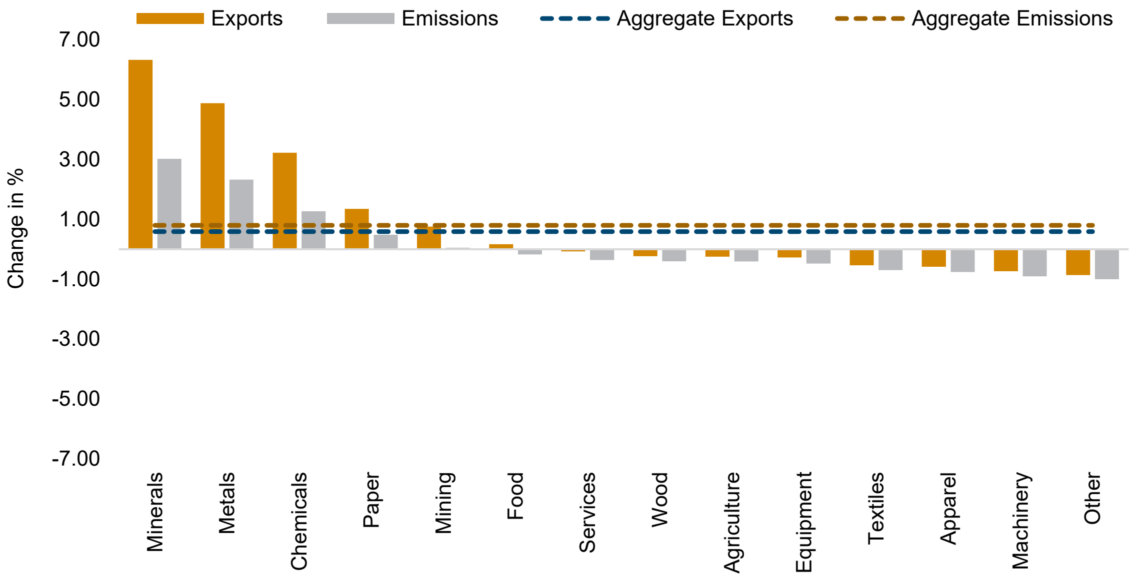
Comprehensive CBA mechanism including carbon tariffs and export rebates

	Exports				Output				Emissions			
Sector	change (in %)	Contribution to % change (in p.p.)	Share in % of total change	Sector share under scenario	change (in %)	Contribution to % change (in p.p.)	Share in % of total change	Sector share under scenario	change (in %)	Contribution to % change (in p.p.)	Share in % of total change	Sector share under scenario
Total economy	0.5888	0.5888	1.0000	1.0000	0.2246	0.2246	1.0000	1.0000	0.7984	0.79836	1.0000	1.0000
Agriculture	-0.2476	-0.0046	-0.0078	0.0183	-0.2041	-0.0033	-0.0147	0.0161	-0.4071	-0.00740	-0.0093	0.0180
Mining	0.7542	0.0038	0.0064	0.0050	0.2537	0.0011	0.0049	0.0044	0.0498	0.00030	0.0004	0.0061
Food	0.1696	0.0080	0.0136	0.0470	0.0314	0.0012	0.0053	0.0380	-0.1720	-0.00266	-0.0033	0.0153
Textiles	-0.5356	-0.0051	-0.0086	0.0094	-0.4948	-0.0038	-0.0170	0.0077	-0.6973	-0.00190	-0.0024	0.0027
Apparel	-0.5852	-0.0051	-0.0087	0.0086	-0.5567	-0.0038	-0.0171	0.0069	-0.7590	-0.00090	-0.0011	0.0012
Wood	-0.2329	-0.0054	-0.0092	0.0232	-0.1994	-0.0039	-0.0174	0.0195	-0.4024	-0.00544	-0.0068	0.0134
Paper	1.3497	0.0425	0.0721	0.0317	0.6877	0.0187	0.0834	0.0274	0.4829	0.01474	0.0185	0.0304
Minerals	6.3219	0.2265	0.3846	0.0379	3.2305	0.1020	0.4543	0.0325	3.0205	0.76282	0.9555	0.2581
Chemicals	3.2215	0.1637	0.2780	0.0521	1.4742	0.0572	0.2545	0.0393	1.2678	0.08377	0.1049	0.0664
Metals	4.8763	0.3120	0.5299	0.0667	2.5343	0.1280	0.5700	0.0517	2.3258	0.10896	0.1365	0.0476
Machinery	-0.7320	-0.0797	-0.1353	0.1074	-0.7038	-0.0572	-0.2549	0.0806	-0.9058	-0.01505	-0.0188	0.0163
Equipment	-0.2767	-0.0165	-0.0281	0.0593	-0.2767	-0.0123	-0.0546	0.0441	-0.4795	-0.00283	-0.0035	0.0058
Other	-0.8597	-0.0122	-0.0207	0.0140	-0.7977	-0.0093	-0.0414	0.0115	-0.9995	-0.00068	-0.0009	0.0007
Services	-0.0746	-0.0390	-0.0662	0.5193	-0.1558	-0.0583	-0.2597	0.3730	-0.3589	-0.14420	-0.1806	0.3972
Non-tradables					0.2763	0.0683	0.3043	0.2475	0.0723	0.00881	0.0110	0.1210

Note: The results refer to price scenario 3 in Section 4. In the CBA mechanism limited to a CBT, the latter is equivalent to carbon costs for EU producers. The comprehensive CBA mechanism assumes rebates for the exports of EU producers to third countries in addition, which are of equal size.
Source: Authors' own work, based on the model by Larch and Wanner (2017).

As these numbers are still very small, it is more telling to consider the IMF tax scenario in the comprehensive CBA mechanism that includes carbon tariffs and export rebates. As the main beneficiary from free allowances, the minerals sector will carry the highest carbon tariff and will benefit from the highest export rebates (see Table 2 for details). As a consequence, it is the minerals sector that experiences the highest increase in exports (+6.3%), followed by the metals (+4.9%) and the chemicals sector (3.2%). Given the decline in exports in most other sectors (which can be attributed to general equilibrium effects), these three sectors together account for 0.7 percentage points, which is more than the aggregate change is Austrian exports which amounts to 0.59%. This pattern also emerges in the sectoral analysis of CO_2 emissions. Figure 5 illustrates the pattern, ranking the industries by the change in exports. As can be seen, the increase in exports and CO_2 emissions are concentrated in a few sectors (mainly the three mentioned above), while the declines are spread over a larger number of sectors and are comparatively small in each of them.

Figure 5 / Sector-level changes in Austrian exports and CO_2 emissions in the IMF tax scenario, comprehensive CBA mechanism including carbon border taxes and export rebates



Note: Industries are ranked by the change in exports.
Source: Results in Table 5, lower panel.

The sectoral effects make clear that, although the results in the aggregate are not really dramatic, the carbon tariffs and the export rebates are very important for individual sectors.[50] This is also the reason why selected industry interest groups are rather concerned by carbon pricing measures and are heavily lobbying and trying to influence the design. For example, in the minerals industry, there is a sizeable difference in terms of expected changes in exports between the limited design of the CBA mechanism in the future ETS price scenario and the comprehensive IMF carbon tax scenario including export rebates. In the former, the industry's exports would increase by an unimpressive 0.08%, while in the latter scenario the gain in exports amounts to more than 6.3%, which is quite substantial.

50 A similar conclusion is made in the sectoral analysis by Kuusi et al. (2020).

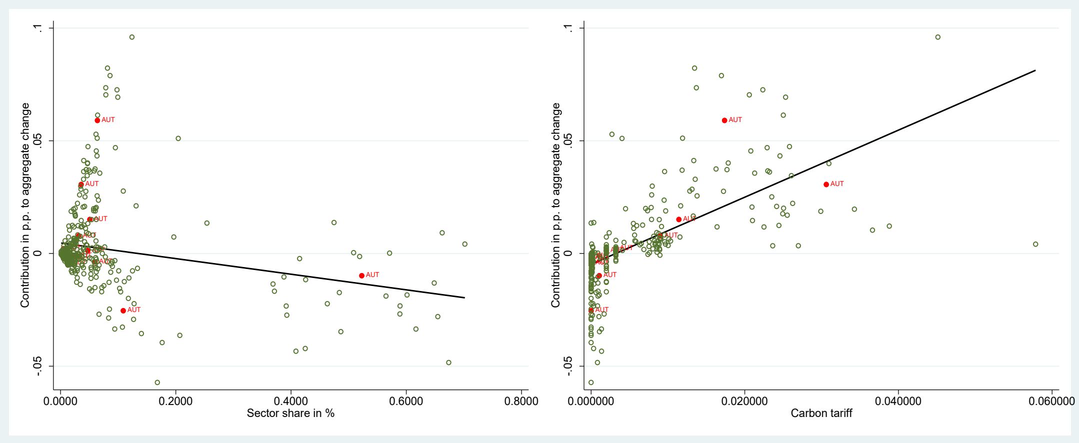
Another important insight from the sectoral results is that the induced structural change may not be the one mandated by the EGD: the CBA mechanism, according to all scenario results and irrespective of the exact design, will lead to a structural shift towards more carbon-intensive industries.[51]

We close this discussion of the sectoral implications of a European CBA mechanism by showing the influence of the size of the carbon tariff and the sector share in the economy on the individual sectors' contributions to the aggregate changes in exports, outputs and emissions. We focus on these two factors as they may be considered the 'usual suspects'. The scatter plots in Figure 6 demonstrate that, for the limited design of the CBA mechanism (that is without export rebates) under the IMF tax scenario, the size of the carbon tariff does indeed matter. The relevance of the sector size is limited, however. In the case of output and CO_2 emissions, on average, a larger sector also contributes more strongly to the change in the respective variable. In the case of exports, though, the influence of the size of the industry-level tariffs on the sector's contribution to the aggregate outcome is especially strong, leaving no role for the sector size in the contribution to aggregate export growth (the correlation is even slightly negative). As the size of tariffs is directly related to emission intensity, the relationship is also strong (and statistically significant) for emissions. Although these correlations are not surprising, they are reassuring insofar as they confirm the decisive role of the carbon tariffs for the results obtained.

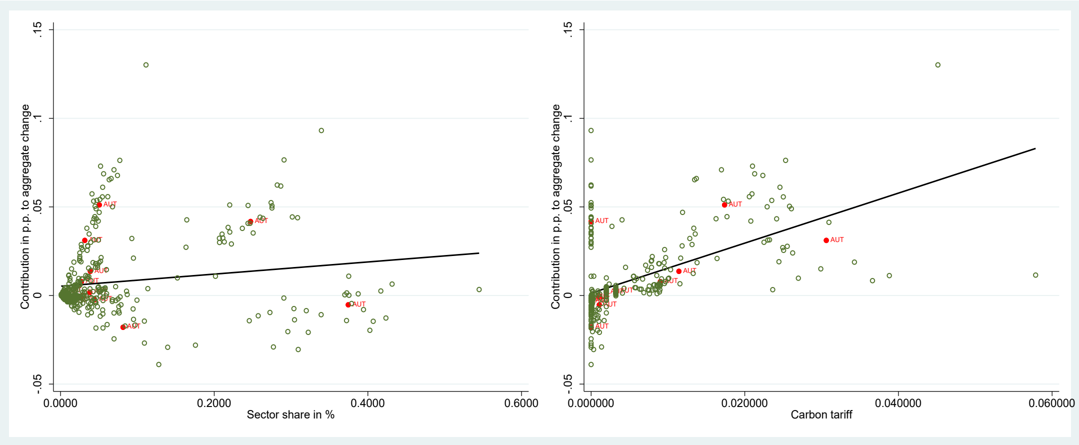
51 According to Monjon and Quirion (2010), a CBA mechanism could also disincentivise European exporters from adopting less CO_2-intensive technologies.

Figure 6 / Sector contributions, sector shares and tariffs, EU member states, IMF carbon tax scenario (CBT)

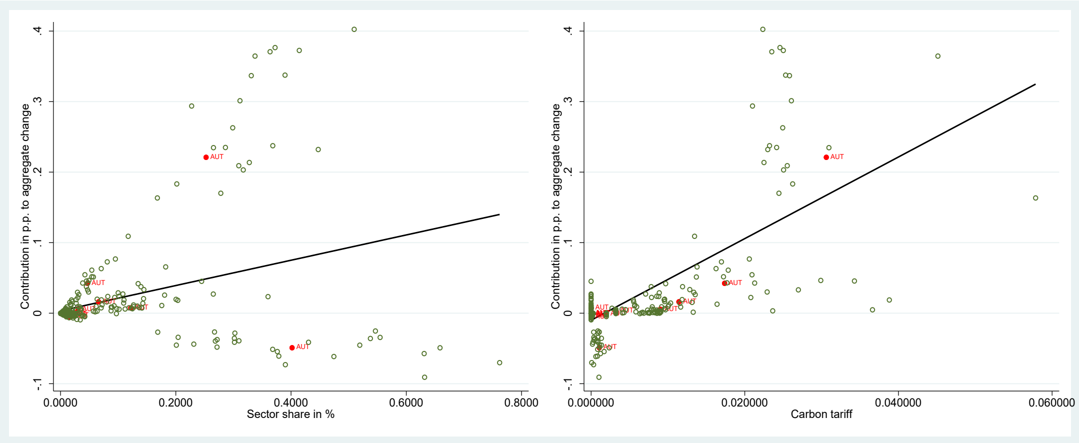
(a) Sectoral contributions (in p.p.) to aggregate exports



(b) Sectoral contributions (in p.p.) to aggregate output



(c) Sectoral contributions (in p.p.) to aggregate emissions



Note: Each observation represents a sector in each of the 27 EU member states. The line is the fit of a pooled panel regression of the sector shares (left panel) and the size of the carbon tariffs (right panel) on the sectors' contribution (in percentage points) to aggregate change in exports, outputs, and emissions.
Source: Authors' own work, based on the model by Larch and Wanner (2017).

5.2.4. The effects of carbon border pricing on FDI

Carbon leakage is not only associated with reduced exports owing to a deterioration of EU firms' international competitiveness, but also with relocations of production either because of a perceived worsening of the locational attractiveness of the EU for new investments (Mehling et al., 2019b), or because FDI has become a more attractive alternative to exporting as a result of carbon tariffs (see Markusen, 2002). Hence, international competitiveness should not only consider exports, but also the attractiveness for inward FDI, i.e., the 'locational competitiveness', as well as the effects of outward FDI by EU firms, which is an alternative way to serve the foreign market. For these reasons, we now use an FDI model that is based on the structural gravity model for FDI by Anderson et al. (2019). The model is derived from a technology capital framework and yields an estimation equation that is very similar to the gravity equation for trade. As it includes an explicit production function, the framework includes labour, physical capital and technology capital as production factors. While labour and physical capital are country-specific, technology capital in the framework of Anderson et al. (2019) is non-rival. Technology capital can best be thought of as patents. If a firm invents a patent, this adds to its country's technology/knowledge capital. Knowledge capital can be used not only by the firm, but it also can allow other firms to use it. In this case, the firm, and therefore its country of residence, earns income, which is what we call FDI earnings. Other countries also have patents, which is their technology capital stock. Each firm can also rely on these foreign inventions for its production, but has to pay for them. This is what we call FDI payments.[52] Most importantly, the framework captures the general equilibrium links between trade and investment in a multi-country world. This implies that, for example, changes in the costs of exporting or importing and their effect on consumer and producer prices will also change the incentives for inward and outward FDI. It therefore captures an additional adjustment margin. As well as deciding whether to sell goods at home or abroad, firms now can decide whether to produce goods at home in order to sell them abroad or, alternatively to use their knowledge to produce goods abroad – that is, serving the foreign market via FDI. Specifically, in their calibrated model investigating the overall effect of FDI, Anderson et al. (2019) conclude that net exports of FDI substitute for export trade. It is therefore of specific interest whether the introduction of a CBA mechanism, leading in the trade model to a slight increase in exports for EU countries, will also increase exports or, instead, as an alternative adjustment channel, will increase FDI and decrease exports.[53]

The framework used contains 89 countries – fewer than in the proposed trade framework owing to missing bilateral FDI data – and uses aggregate flows. However, it will enable the study of changes in the reallocation of resources owing to investments in physical capital and FDI over time. Using the same carbon tariffs as in the trade model (but aggregated to the economy level),[54] it complements the analysis by enabling the quantification of the effects of carbon tariffs not only on trade, but also on FDI and tracking

[52] The payments are equal to the marginal returns on the total stocks of patents (all of the patents contain useful technology, which depreciate, but are still useful patents).

[53] Note that our choice of FDI as non-rival technology capital is focussing on one specific type of FDI. Alternatives would be to focus on horizontal FDI setting up plants abroad to serve the local market or vertical FDI, where production plants abroad produce all or some parts of the goods to exploit factor cost differences (see Markusen, 2002). The choice to focus exclusively on non-rival technology capital was driven by the idea that this type of FDI has the strongest substitution effect to exports, as the investment in FDI can be used in all countries at the same time (in contrast to setting up a plant in one country, as is the case with horizontal and vertical FDI).

[54] In the FDI model, we do not take tariff revenues into account, but treat carbon tariffs as trade costs.

of changes on trade, output, expenditures, physical and technology capital over time until a new steady state is reached.

As for our trade model, we focus on the discussion of the two main scenarios: the 'ETS future price scenario', with the current sector coverage of the ETS and a continued provision of free allowances; and the 'IMF carbon tax scenario', with the assumption of no free allowances being granted for sectors covered by the tax and the current sector coverage of the ETS maintained. For both scenarios, we report results for the CBA mechanism limited to CBTs and for the comprehensive CBA mechanism including CBTs and export rebates. The results for the 'ETS future price scenario' are presented in Table 6, and the results for the 'IMF carbon tax scenario' in Table 7. In addition to total export changes, as well as real GDP and welfare effects,[55] which we also reported for the trade model, we now also report total changes in physical capital stocks. Additionally, and most importantly, we provide several results related to FDI.

First, note that the export effects are negative now for all countries and in both scenarios – the CBA mechanism limited to a CBT and the CBA mechanism including CBTs and export rebates. This is different from the trade model, where exports slightly increase for the EU and EFTA countries in both scenarios, and also for non-EU countries and the world in the CBAM including CBTs and export rebates. Magnitudes between the trade and FDI model naturally vary, as we use different data and a different sample. Specifically, due to missing sectoral, bilateral FDI data, we do not have a sector structure in the FDI model. Hence, the differences in the export results are partly due to the data and the sectoral structure, and partly due to the FDI channel.[56] As our trade model is more detailed, has a sectoral structure and is specifically constructed to evaluate carbon tariffs, we do not discuss the export effects from the FDI model any further. We merely mention that the negative trade effects are larger for the EU (-0.09%) than for the world (-0.07%), and that Austria behaves like a typical EU country. These findings are in line with our trade model.

We will now focus on the new components, the effects on physical and knowledge capital, starting with the CBA mechanism limited to CBTs. Owing to the introduction of carbon tariffs, prices for consumers in the importing countries increase. This also makes investments in physical capital more expensive, leading to a decline in the overall stock of physical capital. The smallest effects are found for countries that are not part of the EU, such as Norway, as they profit from trading with EU partners owing to trade diversion.

For EU countries, the underlying forces driving the changes in physical investments are also those driving the decline in knowledge capital stocks, i.e., the consumer price increase makes investment in knowledge capital stocks more expensive for EU countries. For non-EU countries, several forces are at work. The larger import tariffs will, ceteris paribus, lead to a relative decline in prices at home. This should increase investments in physical and knowledge capital. We see that knowledge capital stocks for China, India, Japan, Russia, and the US are indeed increasing. However, physical capital stocks are not. The reason for this is a shift from investments in physical capital to knowledge capital, as the tariffs introduced make

55 As we do not model emissions explicitly in the FDI model, real GDP and welfare are identical in this framework.

56 In order to disentangle these differences, we also re-run our FDI model without FDI, i.e., perform the same experiments with the aggregate data used in the FDI model but not allowing for FDI. The export effects are partly negative (specifically in the CBA mechanism limited to a CBT) and partly positive when not considering FDI. Importantly, the export effects are always larger as compared to the results when allowing for FDI. This shows the substitutability of exports and our considered FDI. The differences between our trade model with sectoral structure and our FDI model are therefore partly driven by data differences, and partly driven by considering FDI.

it more attractive to export knowledge/invest in FDI rather than investing in (domestic) physical capital used to produce goods that can be exported. FDI earnings for these countries therefore go up, while at the same time these countries' overall exports decline, as already discussed. Note that FDI earnings also go up in EU countries, even though knowledge capital stocks go down. This is explained by increased prices for the use of knowledge capital. As the knowledge capital is used in all countries in the world, and prices go up in EU countries, FDI earnings for EU countries also slightly increase. Austria fits perfectly into this pattern for the EU as a whole as just described. Quantitatively, the decline in physical and knowledge capital stocks is more pronounced in Austria, while the increases in FDI earnings and FDI payments are of a similar magnitude.

For non-EU countries, we see that FDI payments go down, as consumer and producer prices are decreasing in these countries. However, FDI earnings go up, as non-EU countries now invest more in knowledge capital, which is more attractive after the introduction of the tariffs than producing and exporting goods to the EU.

EU countries' FDI payments increase more than their FDI earnings. Overall, we therefore see net inflows of FDI to the EU as the introduction of carbon tariffs makes exporting to the EU less attractive relative to FDI. While overall FDI earnings increase for nearly all countries because the introduction of carbon tariffs makes FDI more attractive relative to exporting, FDI payments increase for some countries and fall for others. Specifically, FDI payments increase the most for EU countries, suggesting that EU trading partners increase their investment in knowledge capital more than EU countries, reflecting the trade-off between exporting and undertaking investments in FDI. Hence, the introduction of carbon tariffs makes the EU more attractive for inward FDI.

In some countries, such as Tunisia, Turkey, and Egypt, FDI payments even decrease, which can be explained by the importance of EU FDI inflows for these countries, which decline owing to EU countries' lower investment in knowledge capital.

Comparing the CBA mechanism limited to CBTs design with the results from the CBA mechanism including CBTs and export rebates, we see that the qualitative patterns are the same. In line with the trade model, the negative effects for exports are mitigated (but are still negative). Furthermore, the real GDP effects are now less negative. The FDI payments and earnings increase substantially. The reason is that investments in knowledge capital only mildly decrease for the EU and increase more strongly for the world overall compared with the scenario without export rebates, as EU exporters are rebated, but prices still increase, leading to increased FDI payments and earnings.

In terms of choice between the two designs, we can note that both designs have similar qualitative outcomes, albeit of different magnitudes. Considering FDI, neither design leads to an increase in exports. However, both induce a switch to knowledge capital, which may be beneficial in terms of emissions as knowledge capital is potentially associated with less carbon-intensive activities. The comprehensive design of the CBA mechanism which includes export rebates for EU producers may also be preferable when taking into account FDI, as the negative effects on exports and welfare are smaller, while the positive FDI earnings effects are larger.

In the IMF carbon tax scenario (Table 7), we see a magnification of the effects, but hardly any change in the qualitative outcomes. This is in line with our findings for the trade model, where the IMF carbon tax scenario also led to larger effects. Specifically, the magnification of the effects also holds for FDI payments and earnings.

Overall, we see that accounting for FDI leads to an additional adjustment channel, where countries shift from exports to FDI when carbon tariffs, and where applicable export rebates, are introduced. For EU countries we find an increase of their `locational attractiveness' for inward FDI. Hence, specifically if one is concerned about the trade effects of carbon tariffs, we think that additionally considering the FDI effects is important and should be studied in more detail in future research. Assuming that knowledge capital is related to inventions and production that is less carbon-intensive, this should help to revert carbon leakage further, while mitigating the negative effects on real GDP and welfare.

Table 6 / FDI-effects of a CBA mechanism limited to a CBT and a comprehensive CBA mechanism including export rebates, future ETS price scenario

	percentage change in											
	CBAM limited to carbon tariffs						CBAM including carbon tariffs and export rebates					
country	Exports	Physical capital	Knowledge capital	FDI payments	FDI earnings	Welfare (in terms of real GDP)	Exports	Physical capital	Knowledge capital	FDI payments	FDI earnings	Welfare (in terms of real GDP)
AUT	-0.0719	-0.0238	-0.0246	0.0350	0.0178	-0.0249	-0.0208	-0.0065	-0.0090	0.1004	0.0549	-0.0094
DEU	-0.1109	-0.0213	-0.0223	0.0337	0.0160	-0.0221	-0.0599	-0.0113	-0.0131	0.0884	0.0513	-0.0129
FRA	-0.1282	-0.0212	-0.0235	0.0395	0.0162	-0.0228	-0.0780	-0.0127	-0.0161	0.0942	0.0518	-0.0157
ITA	-0.1523	-0.0200	-0.0235	0.0409	0.0162	-0.0217	-0.1086	-0.0141	-0.0179	0.0902	0.0520	-0.0167
POL	-0.0956	-0.0149	-0.0169	0.0460	0.0169	-0.0165	-0.0642	-0.0094	-0.0113	0.0938	0.0535	-0.0115
SVN	-0.0566	-0.0032	-0.0046	0.0486	0.0186	-0.0036	0.0009	0.0003	-0.0016	0.1054	0.0569	-0.0005
SWE	-0.0413	-0.0113	-0.0113	0.0277	0.0185	-0.0117	-0.0142	-0.0016	-0.0017	0.0837	0.0562	-0.0027
AUS	-0.0300	-0.0017	-0.0004	-0.0015	0.0171	-0.0012	-0.0078	0.0009	0.0042	0.0059	0.0541	0.0022
BRA	-0.0650	-0.0035	0.0000	-0.0077	0.0197	-0.0022	-0.0228	0.0002	0.0075	0.0010	0.0580	0.0028
CHE	-0.0299	-0.0042	-0.0041	0.0213	0.0167	-0.0043	-0.0666	-0.0066	-0.0062	0.0503	0.0537	-0.0065
CHN	-0.0692	-0.0043	0.0101	-0.0083	0.0174	-0.0024	-0.0277	-0.0008	0.0297	0.0017	0.0542	0.0030
ETH	-0.0898	-0.0113	0.0039	-0.0221	0.0248	-0.0106	-0.0285	-0.0034	0.0222	-0.0058	0.0688	-0.0022
GBR	-0.0004	-0.0002	-0.0002	0.0255	0.0165	-0.0009	-0.0179	-0.0020	-0.0004	0.0569	0.0530	-0.0023
IND	-0.0744	-0.0047	0.0149	-0.0075	0.0178	-0.0022	-0.0286	-0.0006	0.0417	0.0018	0.0551	0.0045
JPN	-0.0385	-0.0023	0.0153	-0.0049	0.0174	-0.0009	-0.0132	-0.0001	0.0404	0.0035	0.0544	0.0029
RUS	-0.1704	-0.0050	0.0038	-0.0166	0.0186	-0.0041	-0.0614	-0.0014	0.0157	-0.0085	0.0565	0.0002
SAU	-0.0610	-0.0040	-0.0010	-0.0040	0.0237	-0.0036	-0.0172	-0.0005	0.0069	0.0024	0.0687	0.0004
TUR	-0.1544	-0.0211	-0.0160	-0.0284	0.0178	-0.0190	-0.0547	-0.0061	0.0022	-0.0120	0.0552	-0.0029
USA	-0.0555	-0.0034	0.0040	-0.0054	0.0183	-0.0018	-0.0176	0.0001	0.0164	0.0045	0.0562	0.0035
ZAF	-0.0632	-0.0039	-0.0030	-0.0066	0.0183	-0.0034	-0.0141	0.0007	0.0027	0.0023	0.0560	0.0018
EU	-0.0914	-0.0155	-0.0157	0.0379	0.0167	-0.0158	-0.0498	-0.0080	-0.0082	0.0977	0.0529	-0.0087
EFTA	-0.0157	-0.0009	-0.0031	0.0234	0.0166	-0.0025	-0.0415	-0.0011	-0.0044	0.0542	0.0532	-0.0034
World	-0.0734	-0.0074	0.0006	0.0177	0.0177	-0.0062	-0.0349	-0.0026	0.0130	0.0549	0.0549	-0.0008

Note: The results refer to price scenario 2 in Section 4. In the CBA mechanism limited to a carbon border tax, the latter is equivalent to carbon costs for EU producers. The comprehensive CBA mechanism assumes rebates for the exports of EU producers to third countries in addition, which are of equal size.
Source: Authors' own work, based on the model by Anderson et al. (2019).

Table 7 / FDI-effects of a CBA mechanism limited to a CBT and a comprehensive CBA mechanism including export rebates, IMF carbon tax scenario

	percentage change in											
	CBAM limited to carbon tariffs						CBAM including carbon tariffs and export rebates					
Country	Exports	Physical capital	Knowledge capital	FDI payments	FDI earnings	Welfare (in terms of real GDP)	Exports	Physical capital	Knowledge capital	FDI payments	FDI earnings	Welfare (in terms of real GDP)
AUT	-0.2497	-0.0826	-0.0856	0.1303	0.0667	-0.0867	-0.0176	-0.0038	-0.0147	0.4644	0.2637	-0.0166
DEU	-0.4294	-0.0825	-0.0861	0.1257	0.0601	-0.0854	-0.1508	-0.0277	-0.0369	0.4215	0.2472	-0.0354
FRA	-0.4132	-0.0684	-0.0759	0.1418	0.0610	-0.0741	-0.1811	-0.0288	-0.0420	0.4260	0.2502	-0.0412
ITA	-0.5928	-0.0776	-0.0907	0.1531	0.0611	-0.0839	-0.2435	-0.0321	-0.0559	0.4504	0.2504	-0.0458
POL	-0.3440	-0.0537	-0.0608	0.1697	0.0634	-0.0594	-0.1600	-0.0219	-0.0300	0.4338	0.2575	-0.0312
SVN	-0.2165	-0.0120	-0.0172	0.1798	0.0700	-0.0138	0.0026	0.0016	-0.0055	0.4651	0.2727	-0.0015
SWE	-0.1822	-0.0497	-0.0496	0.1052	0.0696	-0.0512	0.0081	0.0137	0.0127	0.4253	0.2686	0.0072
AUS	-0.1112	-0.0061	-0.0013	-0.0050	0.0644	-0.0043	0.0081	0.0074	0.0222	0.0386	0.2601	0.0134
BRA	-0.2406	-0.0128	0.0000	-0.0281	0.0741	-0.0081	-0.0137	0.0065	0.0394	0.0221	0.2766	0.0183
CHE	-0.1095	-0.0153	-0.0150	0.0797	0.0628	-0.0158	-0.2994	-0.0278	-0.0260	0.2382	0.2589	-0.0272
CHN	-0.2534	-0.0158	0.0378	-0.0299	0.0653	-0.0089	-0.0339	0.0027	0.1376	0.0280	0.2603	0.0196
ETH	-0.3495	-0.0440	0.0140	-0.0862	0.0933	-0.0413	-0.0151	-0.0007	0.1095	0.0041	0.3300	0.0042
GBR	-0.0011	-0.0006	-0.0004	0.0950	0.0620	-0.0031	-0.0884	-0.0093	-0.0018	0.2644	0.2555	-0.0100
IND	-0.2765	-0.0173	0.0560	-0.0273	0.0671	-0.0082	-0.0426	0.0034	0.1908	0.0281	0.2644	0.0263
JPN	-0.1427	-0.0084	0.0575	-0.0177	0.0654	-0.0035	-0.0117	0.0028	0.1843	0.0322	0.2616	0.0165
RUS	-0.6320	-0.0186	0.0143	-0.0615	0.0699	-0.0153	-0.0496	0.0009	0.0759	-0.0138	0.2704	0.0079
SAU	-0.2229	-0.0144	-0.0033	-0.0137	0.0891	-0.0130	0.0128	0.0041	0.0371	0.0253	0.3242	0.0083
TUR	-0.5563	-0.0761	-0.0572	-0.1008	0.0672	-0.0682	-0.0156	0.0052	0.0398	-0.0103	0.2643	0.0181
USA	-0.2054	-0.0124	0.0151	-0.0194	0.0686	-0.0066	-0.0127	0.0050	0.0780	0.0384	0.2696	0.0203
ZAF	-0.2363	-0.0146	-0.0112	-0.0248	0.0688	-0.0127	0.0233	0.0096	0.0185	0.0272	0.2687	0.0144
EU	-0.3331	-0.0564	-0.0584	0.1414	0.0629	-0.0581	-0.1079	-0.0152	-0.0198	0.4531	0.2549	-0.0203
EFTA	-0.0567	-0.0032	-0.0111	0.0875	0.0623	-0.0089	-0.1902	-0.0044	-0.0184	0.2557	0.2565	-0.0140
World	-0.2682	-0.0271	0.0024	0.0665	0.0665	-0.0228	-0.0625	-0.0012	0.0654	0.2638	0.2638	0.0059

Note: The results refer to price scenario 3 in Section 4. In the CBA mechanism limited to a carbon border tax, the latter is equivalent to carbon costs for EU producers. The comprehensive CBA mechanism assumes rebates for the exports of EU producers to third countries in addition, which are of equal size.
Source: Authors' own work, based on the model by Anderson et al. (2019).

6. Conclusions

As the publication of a first proposal by the European Commission for the European CBA mechanism, announced for 2021, is approaching, it is important to understand the economic and environmental implications of alternative designs of such a mechanism. To this end and with a view to informing the decision-making process, this study analyses and compares a series of alternative scenarios, which differ along several dimensions of a potential CBA mechanism.

A first obvious differentiation criterion is **the price for CO_2, which feeds into the resulting carbon tariffs and therefore directly affects the effectiveness of the CBA mechanism**. Secondly, there is the **basic design question**, that is, whether the CBA mechanism is to consist of a **carbon border tax only**, or whether it is to take the form of a comprehensive CBA mechanism that comprises **export rebates in addition to a CBT**. Thirdly, the underlying domestic carbon pricing mechanism (ETS versus carbon tax) may matter. This can influence the extent to which **exceptions for emission-intensive industries in the form of free allowances are granted**. Therefore, out of the numerous scenarios calculated, two main scenarios are defined: the first one is labelled **'future ETS price scenario'**, which assumes a carbon price of EUR 44 (acknowledging that it is below the current price of emission allowances within the ETS) and a continuation of the current practice of free allowances; the other is labelled **'IMF carbon tax scenario'** and assumes a carbon price of EUR 67, which is taken from a recent publication by the IMF, and that free allowances in the industries by the CBA mechanism are abandoned. For each scenario, both basic design options are compared. All scenarios take the current industry coverage of the ETS as a given and assume that this coverage is taken over for the application for the CBA mechanism. The analysis undertaken with a sector-specific quantitative trade model, and backed by a model that also features an FDI channel, leads to the following main conclusions.

- The planned European CBA mechanism is going to be **effective in supporting its twin objectives** of (a) restoring the competitiveness of energy-intensive EU industries that are burdened by the carbon costs imposed on them by the ETS; and (b) attenuating the carbon leakage effect.
- Within a reasonable range of carbon prices and applied to the current ETS industries, **the economic and environmental effects of a European CBA mechanism are going to be very small**. Hence, even the EUR 67 in the IMF carbon tax scenario do not seem to qualify as a 'high' carbon price.
- The small economic effects at the aggregate level mask **more significant changes at the industry level**, with the minerals, chemicals and metals sectors being the parts of the economy that are most strongly affected, owing to their energy-intensity.
- The **preferable design for the CBA mechanism is a comprehensive CBA mechanism** that also includes export rebates. This conclusion is motivated by the fact that such a design option implies an **improvement of European export competitiveness *and* results in lower global emissions**.
- Irrespective of the basic design choice, the introduction of a CBA mechanism **calls for the discontinuation of the current system of free allowances.** The allocation of free allowances to energy-intensive industries reduces the effective carbon costs for EU producers, which will in turn be reflected in lower CBTs, thereby undermining the purpose of the CBA mechanism. This does not come

as a surprise, given that the granting of free allowances is also an instrument to level the playing field and to avoid carbon leakage effects. As these are also exactly the objectives of a CBA mechanism, the two instruments – **CBA mechanism on the one hand and free allowances on the other – are to be seen as alternatives, rather than supplements**. Mixing the two, as has recently been suggested in the literature, would unduly complicate the European pricing system and make it non-transparent, thereby putting at risk its compatibility with WTO rules.

› The implementation of a CBA mechanism by a wider range of environmentally ambitious countries would strengthen the effectiveness of such a scheme compared with unilateral EU action and would therefore clearly be preferable. For the EU, however, the results arising from such a 'carbon club' arrangement would not be substantially different.

› The FDI channel, which for some firms is an alternative to serving foreign markets via exports, could potentially change the results and tends to weaken the positive impact of the CBA mechanism on the EU's export competitiveness. To what extent firms' possibility to switch to FDI following the introduction of carbon tariffs is hard to pin down but it could potentially be a very important margin of adjustment.

› Based on these findings, the following policy recommendations are derived.

› Given the effectiveness of the CBA mechanism to reach the set objectives, the EU should proceed with its plan to implement such a mechanism by 2023.

› In view of the limited magnitude of the economic and environmental effects induced by the CBA mechanism, it should be seen as just one of many tools in the fight against climate change.

› The introduction of a CBA mechanism calls for the discontinuation of the current practice of free allowances of emission certificates within the European ETS, in spite of recent proposals to incorporate them into a modified CBA mechanism.

› The formation of a climate club would be the preferable option, but the additional effects to be obtained by the EU compared with unilateral action do not justify postponing the implementing the European CBA mechanism.

› The CBA mechanism is more effective when designed in a comprehensive manner, including a CBT and export rebates, which therefore emerges as the preferred design option.

These recommendations are derived from an interpretation of the economic and environmental effects against the specific objectives of a CBA mechanism. They come, however, with a full list of **qualifications** which policy makers also need to take into account.

› There is a trade-off between the specific objectives of the CBA mechanism and the EU's general emission-reduction objectives. The **reversal of the supposed carbon leakage effect implies shifting some emission-intensive activities back into the EU** (which have previously been moved to third countries with lower domestic carbon costs). Although this is in line with the specific objective of the CBA mechanism, the resulting increase in CO_2 emissions goes against the spirit of the European Green Deal (EGD). This trade-off can be solved by combining the introduction of the CBA mechanism in tandem with other regulatory measures to reduce carbon emissions. In other words, being a second-best solution, the CBA mechanism should not be a stand-alone instrument.

- Another environmentally related aspect that has received comparatively little attention so far in the literature is the fact that a **European CBA mechanism will induce a structural change towards more energy and emission-intensive industries**, which is again not in alignment with the objectives of the EGD.
- Another aspect to be taken seriously is the fact that the constellation of raising CO_2 emissions in the EU, a push for EU exports, and declining CO_2 emissions in third countries will intensify the **assessment of trading partners that the CBA mechanism is nothing but green protectionism in disguise**.
- With regard to the design options, the expressed preferences for the comprehensive CBA mechanism including a CBT and export rebates, is to be qualified insofar as its economic and environmental advantages need to be weighed against the additional legal risks, i.e. the potential conflict of export rebates with the EU's obligations under the WTO.
- More generally, **the FDI channel may significantly weaken the export competitiveness effect**. If firms can use the FDI investment channel to serve foreign markets, then – given the higher cost of exporting after the implementation of a CBT, and where applicable export rebates – firms will make more intensive use of the FDI option. In this vein, the quantitative results obtained from an aggregate FDI model suggest that EU exports may in fact decrease after the implementation of a CBA mechanism. And while the FDI channel works against the export competitiveness effect identified in the trade model, it is also true that the EU's locational competitiveness (attracting FDI) and EU firms additional outward FDI activities are also evidence of international competitiveness as are higher exports.

In addition to these qualifications, all of which are related to the interpretation of the results, there are also some **limitations of this study**, which are of a methodological nature but should also be kept in mind and sketch an agenda for future research on the topic of CBA measures. First, the study analysed the economic and environmental effects of introducing a European CBA mechanism. Although the models employed are capable of capturing general equilibrium effects, they are **silent on any potential retaliation effects**. In the same manner, the study does **not reflect knock-on effects, in particular the possibility that some trading partners may be induced to introduce a domestic carbon pricing system in order to avoid facing tariffs when exporting to the EU**. This should be kept in mind, as bringing other countries into the 'carbon club' is an explicit objective of the EGD. Second, the comparative static analysis in this **study omits adjustment costs as well as long-run technological change**. While omitting adjustment costs may lead to an underestimation of the costs of adjusting production and trade as a result of the introduction of carbon taxes, not taking long-term technological changes into account may lead to overestimation, specifically of the emission effects. Third, the trade model treats the **electricity generation sector as part of the non-tradable sector**. This is fully justifiable, given the low tradability of the sector, but is to be mentioned for the sake of completeness as carbon tariffs for this sector would be one of the highest. Fourth, in this study the main results were obtained from a trade model with a rich industry structure. These results were supplemented with additional insights from a separate model that also features FDI. The latter model, however, uses aggregate data and therefore lacks the sector details which are also important. At the same time, the FDI model revealed that the FDI channel could indeed be an important margin of adjustment that should be analysed in more detail in future research.

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Appendix

A.1 DATA

Given the scope and complexity of the quantitative analysis, it will have to draw on numerous data sources. The most important ones are summarised in Table A.1.

Table A.1 / Main data sources for the analysis of the effects of a European CBT.

Data source	Variables / Use
WIOD Release 2016 *Available at: http://www.wiod.org/release16*	Global Input-Output data for 43 economies (2000-2014)
WIOD Environmental Accounts *Available at: https://ec.europa.eu/jrc/en/research-topic/economic-environmental-and-social-effects-of-globalisation*	CO_2 emissions at the industry level matching the country and industry structure of the WIOD
GTAP 8 Data Base *Available at:* https://www.gtap.agecon.purdue.edu/databases/default.asp	Trade, production, energy, and emission data
UNCTAD FDI database *Available at: https://unctad.org/en/Pages/DIAE/FDI%20Statistics/FDI-Statistics-Bilateral.aspx*	Bilateral FDI data at the aggregate level
OECD FDI database *Available at: https://www.oecd.org/investment/fdiindex.htm*	FDI Regulatory Restrictiveness Index for countries' FDI openness, covering OECD and non-OECD countries
UNESCO Institute for Statistics (UIS) *Available at: http://uis.unesco.org/en/news/rd-data-release*	Country-level R&D expenditure (measure for knowledge capital)
Penn World Table version 9.1 *Available at: https://www.rug.nl/ggdc/productivity/pwt/?lang=en*	Aggregate macroeconomic data
World Health Organisation (WHO) *Available at: https://www.who.int/gho/database/en/*	Disability Adjusted Life Years (DALYs) attributable to the environment

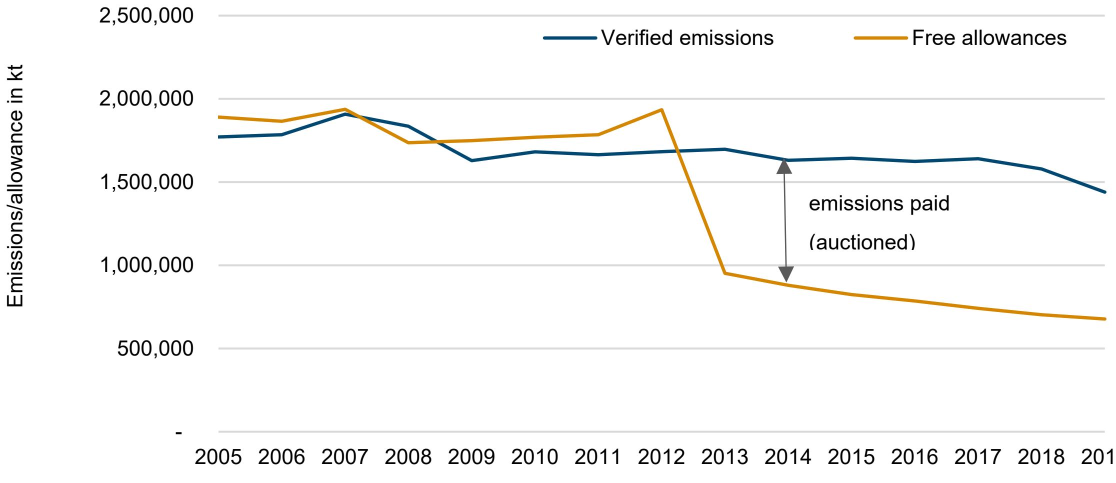
A.2 CO_2 EMISSIONS, VERIFIED EMISSIONS, AND FREE ALLOCATIONS IN THE ETS

A.2.1 Correspondence between ETS industries and Standard Industry Classifications (NACE Rev2/WIOD)

The construction of the scenarios and the implied CO_2 tariffs relied on four major data sources. The first of these data sources was the ETS database[57] from which the number of verified emissions of CO_2 equivalents within the ETS system were obtained. This is the sum of emissions by installations registered in the ETS that were verified (across all so-called 'categories'). The ETS database also provides information on the number of free allowances granted to each participating country. The number of verified emissions is available at the level of each category and the same is true for free emissions. In contrast, the ETS database does not hold information on the emissions paid at the category level, but only at the aggregate level (for all industrial sectors and aviation). Therefore, we need to calculate the number of paid emissions at the category level as the difference between verified emissions and free emissions.[58]

The total volume of emissions across all ETS categories and the free allowances for the EU27 are shown in Figure A.1.

Figure A.1 / Total verified emissions and free allowances in the European ETS system, EU27, 1995-2019



Note: Emissions and free allowances in all ETS categories (including industrial installations and aviation). The peak in free emissions in 2012 is due to the inclusion of the aviation sector.
Source: ETS Database. Available at: https://www.eea.europa.eu/data-and-maps/data/european-union-emissions-trading-scheme-14.

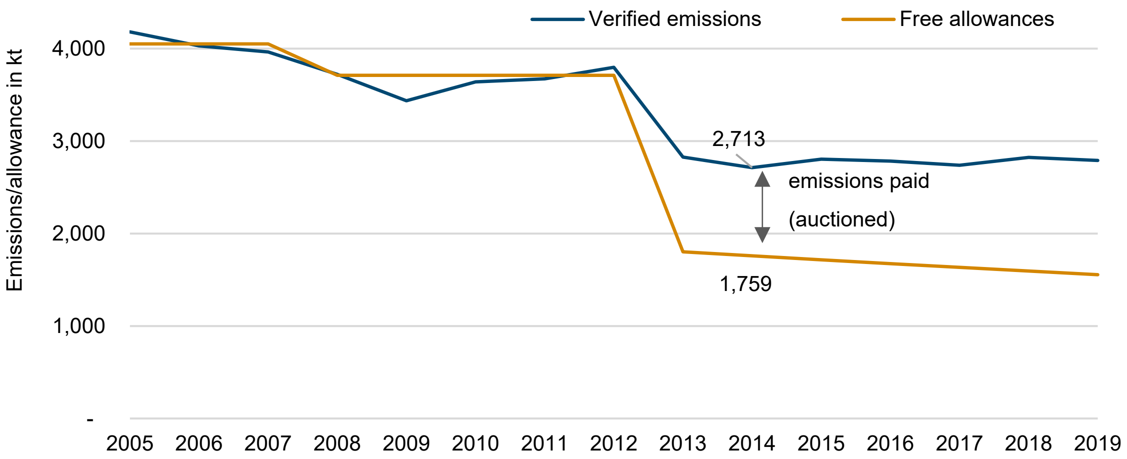
Most of the ETS categories (i.e. sectors) can correspond one to one to a NACE industry. For example, the ETS categories '21 Refining of mineral oil' and '22 Production of coke' both match the NACE Rev.2

[57] Available at: https://www.eea.europa.eu/data-and-maps/data/european-union-emissions-trading-scheme-14.

[58] The sum of free allowances and paid allowances equals the total number of allowances in each year. However, the number of total allowances does not coincide exactly with number of verified emissions because firms can carry over EAUs from one year to the next. Moreover, allowances can be sold and bought (auctioned) across ETS industries.

industry ‘Manufacture of coke and refined petroleum products’ (NACE 19). The identification of the allowances that have to be paid for by EU companies at the ETS sector level is done in the same way as described above, as the difference between the verified emissions and the free allowances as shown in Figure A.2 for the Austrian coke and petroleum industry.

Figure A.2 / Verified emissions and free allowances in the production of coke and refining of mineral oil, Austria, 1995-2019



Note: Production of coke and refining of mineral oil corresponds to ETS categories 21 & 22 and NACE Rev 2. industry 19 (coke and refined petroleum products).
Source: ETS Database. Available at: https://www.eea.europa.eu/data-and-maps/data/european-union-emissions-trading-scheme-14

In fact, the identification of allowances must be done at an individual ETS sector level for each EU member state. This is important because excess free allowances in, say, the German ETS sector ‘Production of bulk chemicals’ (42), does not mean that an excess demand of allowances in the Finnish paper ETS sector ‘Production of pulp’ (35), do not have to be paid for in the latter.[59] In other words, we assume that an excess supply of free allowances in one ETS sector does not cancel out excess demand of allowances in another ETS sector.

In the ETS category ‘combustion of fuel’ (20), there is one category that has no correspondence with a NACE industry. The bulk, about 75% of the emissions in this ETS category, is attributable to power stations (with a capacity of 20MW or more) (Gores et al., 2019) and can therefore be assigned to the electricity sector *(D35 – Electricity, gas, steam and air conditioning supply)*. However, the ETS category ‘combustion of fuel’ also comprises industrial installations that are listed in Annex I of the ETS Directive. The guiding document to this Annex I (European Commission, 2010, p. 6) states that *‘… the activity “combustion of fuels” can occur in all types of NACE categories, not only industrial ones. Examples of such non-industrial installations are combustion units in greenhouses, hospitals, universities and office buildings, booster stations in natural gas transport networks etc.’*

[59] Of course, in this example, the German firm that sells the allowances earns additional income, but we have no information on which firms in which sectors sell allowances, who they sell them to, or whether they sell them at all.

Hence, firms across all NACE can potentially be covered by the ETS and therefore all NACE industries can at least be partially required to purchase emissions allowances. We have found a list of installations covered by the ETS system as of 2012 indicating both the primary NACE industry code and the ETS category 'combustion of fuel'. We use this list to assign (at the level of individual member states) the CO_2 emissions from the ETS category 'combustion of fuel' to the different NACE industries. The result is listed in Table A.2.

This procedure assigns more than 80% of verified emissions from the combustion of fuel to the NACE industry 'Electricity, gas, steam and air conditioning supply' (D35). Important shares also end up in the chemicals industry and the basic metals industry.

Table A.2 / Assignment of ETS sector 'Combustion of fuels' (20) to NACE Rev.2 industries /WIOD industries, 2012

NACE industry code	NACE industry name	Verified emissions	free allowances	paid allowances
A01	Crop and animal production, hunting	0.04%	0.05%	0.04%
B	Mining and quarrying	0.21%	0.40%	0.15%
C10-C12	Food products, beverages and tobacco	2.91%	2.15%	3.20%
C13-C15	Textiles, wearing apparel and leather	0.01%	0.01%	0.01%
C16	Wood and of products of wood and cork	0.03%	0.05%	0.02%
C17	Paper and paper products	0.02%	0.04%	0.01%
C18	Printing and reproduction of recorded media	0.15%	0.05%	0.18%
C19	Coke and refined petroleum products	0.08%	0.16%	0.05%
C20	Chemicals and chemical products	7.10%	8.90%	6.42%
C21	Basic pharmaceutical products	1.68%	1.52%	1.75%
C22	Rubber and plastic products	0.07%	0.08%	0.06%
C23	Other non-metallic mineral products	0.05%	0.05%	0.05%
C24	Basic metals	3.91%	7.44%	2.59%
C25	Fabricated metal products	0.00%	0.01%	0.00%
C27	Electrical equipment	0.00%	0.00%	0.00%
C28	Machinery and equipment n.e.c.	0.01%	0.01%	0.00%
C29	Motor vehicles, trailers and semi-trailers	0.10%	0.09%	0.10%
C30	Other transport equipment	0.10%	0.20%	0.07%
C31_C32	Furniture; other manufacturing	0.00%	0.00%	0.00%
C33	Repair and installation of machinery and eq.	0.00%	0.00%	0.00%
D35	Electricity, gas, steam supply	83.37%	78.53%	85.17%
E37-E39	Sewerage; waste collection, treatment	0.01%	0.01%	0.00%
F	Construction	0.00%	0.00%	0.00%
H49	Land transport and transport via pipelines	0.09%	0.16%	0.06%
H52	Warehousing	0.04%	0.07%	0.03%
L68	Real estate activities	0.00%	0.00%	0.00%
O84	Public administration and defence	0.00%	0.00%	0.01%
P85	Education	0.00%	0.00%	0.00%
Q	Human health and social work activities	0.01%	0.02%	0.01%
A-Q	All NACE industries	100.00%	100.00%	100.00%

Note: Emissions are assigned to NACE industries at the member states' specific level for the ETS category *'Combustion of fuels' (20)*.
Source: ETS Database. Available at: https://www.eea.europa.eu/data-and-maps/data/european-union-emissions-trading-scheme-14

We omit the emissions under the category *'99 Other activity opted-in under Art. 24',* as these are different industries that member states decided to be included in the EU ETS. This is because the guide to the EU

ETS allowances database states that 'the nature of such activities could be very diverse across the 13 countries that opted-in installations falling into this category'. However, this is not an important exclusion, as these opt-in installations only accounted for 0.05% of the total emissions of stationary installations in 2014.

In this way, we can construct a correspondence between ETS sectors and NACE industries to be used for calculating the implicit carbon tariff equivalents (Table A.3). This correspondence to NACE industries enables the linking of data from the ETS database to the WIOD's International Input-Output Table (WIOT) (Timmer, et al., 2015) and the associated Socio-Economic Account (SEA) for CO_2 emissions developed by the Joint Research Centre associated to the European Commission (Corsatea et al., 2019).

Table A.3 / Correspondence between ETS sector and to NACE Rev.2 industries /WIOD industries, 2012

ETS code	ETS sector name	WIOD code	WIOD name
10	10 Aviation	H51	Air transport
20	*20 Combustion of fuels*		*See Table A.2 for split*
21	21 Refining of mineral oil	C19	Coke and refined petroleum products
22	22 Production of coke	C19	Coke and refined petroleum products
23	23 Metal ore roasting or sintering	B	Mining and quarrying
24	24 Production of pig iron or steel	C24	Basic metals
25	25 Production or processing of ferrous metals	C24	Basic metals
26	26 Production of primary aluminium	C24	Basic metals
27	27 Production of secondary aluminium	C24	Basic metals
28	28 Production or processing of non-ferrous metals	C24	Basic metals
29	29 Production of cement clinker	C23	Other non-metallic mineral products
30	30 Production of lime	C23	Other non-metallic mineral products
31	31 Manufacture of glass	C23	Other non-metallic mineral products
32	32 Manufacture of ceramics	C23	Other non-metallic mineral products
33	33 Manufacture of mineral wool	C23	Other non-metallic mineral products
34	34 Production or processing of gypsum or plasterboard	C23	Other non-metallic mineral products
35	35 Production of pulp	C17	Paper and paper products
36	36 Production of paper or cardboard	C17	Paper and paper products
37	37 Production of carbon black	C20	Chemicals and chemical products
38	38 Production of nitric acid	C20	Chemicals and chemical products
39	39 Production of adipic acid	C20	Chemicals and chemical products
40	40 Production of glyoxal and glyoxylic acid	C20	Chemicals and chemical products
41	41 Production of ammonia	C20	Chemicals and chemical products
42	42 Production of bulk chemicals	C20	Chemicals and chemical products
43	43 Production of hydrogen and synthesis gas	C20	Chemicals and chemical products
44	44 Production of soda ash and sodium bicarbonate	C20	Chemicals and chemical products
45	45 Capture of greenhouse gases under Dir.2009/31/EC	C26	Computer, electronic and optical products
46	46 Transport of greenhouse gases under Dir.2009/31/EC	H49	Land transport and transport via pipelines

As we use official data from the ETS database, Table A.3 reflects the sectors covered by the ETS as reported by the European Commission.[60]

60 According to the Commission website (https://ec.europa.eu/clima/policies/ets_en), emissions of greenhouse gases from the following industries are covered: (i) power and heat generation; (ii) energy-intensive industry sectors comprising oil refineries, steel works and production of iron, aluminium, metals, cement, lime, glass, ceramics, pulp, paper, cardboard, acids, and bulk organic chemicals; and (iii) commercial aviation (coverage is limited to flights between destinations within the European Economic Area).

A.2.2 Verified emissions, free allowances and total emissions

The information on the verified CO_2 emissions by EU member states[61] and ETS sectors comes from the ETS database provided by the European Environmental Agency.[62] This dataset provides verified emissions along with total allowances issued. Importantly, the allowances (EUAs) are further split into free allowances and allowances that firms bought or sold via the auctioning mechanism. For our purposes, the verified emissions (CO_2) and the free allowances (EUA^f) that were provided in each member state are provided at the ETS sector level. In contrast, the number of allowances paid are only available at the aggregate level. For this reason, we calculate (at the country and ETS category level) the volume of emissions that EU firms in each member state actually had to pay for (EUA^p) as the difference between the emissions covered by the EU ETS, i.e., the verified emission (CO_2^v) and the number of free allowances (*EUA*). Denoting member states by c and industries by k, the allowances paid are calculated as follows:

$$EUA_k^p = CO2_k^v - EUA_k^f$$

The expression on the right-hand side is used in equation (1) and equation (2) of the main text to calculate the tariff equivalent of the carbon border tax and the carbon border rebate, respectively.

As trade policy is an exclusive competence of the EU, the implicit carbon tariffs/rebates are calculated based on industry-level payable emissions and gross output for the EU as a whole. This way, we obtain the same tariff/export rebate for any industry across all member states.

A technical note is warranted at this stage. There are some industries that are not covered by the ETS in their entirety. Instead, only major installations of the sector are covered, i.e., if they qualify for the ETS category 'combustion of fuel' but are part of a NACE industry that is as such not covered by the ETS. In this case, the verified emissions in the industry are much lower than the industry's total CO_2 emissions.

The distinction between verified emissions in the ETS and an industry's total emissions is therefore important. The verified emissions are taken from the ETS database; the total number of emissions are taken from the WIOD's environmental satellite accounts. This distinction is also important for the definition of scenarios. The scenarios that assume the current ETS sector coverage use the verified emissions ($CO2_k^v$) for calculating implicit carbon costs. In contrast, the scenarios that assume total sector coverage use each industry's total CO_2 emissions ($CO2_k^{total}$) according to the WIOD environmental satellite accounts. Hence the variable $CO2_k$ in equations (1) and (2) of the main text denote verified emissions or total emissions of a sector depending on the scenario assumption:

$$CO2_k = \begin{cases} CO2_k^v \text{, if scenario assumes industry coverage as in current ETS} \\ CO2_k^{total} \text{, if scenario assumes complete industry coverage} \end{cases}$$

This approach is feasible, as the data from the WIOD environmental satellite accounts perfectly matches the ETS database. This match was checked with the help of NACE industries that are fully covered by the ETS, such as the coke and refined petroleum products industry (NACE C19).

61 The database also includes information for participating EFTA members, i.e., Iceland, Liechtenstein and Norway.

62 The data are publicly available at: https://www.eea.europa.eu/data-and-maps/data/european-union-emissions-trading-scheme-14

The ETS data and the WIOD data were merged for the year 2014, which is the most recent year for which output data is available in the WIOD.

A.2.3 Correspondence between WIOD industries and GTAP sectors

In a last step, the implicit CBT and implicit carbon border rebates that were calculated at the level of WIOD industries are aggregated to the level of GTAP sectors. For WIOD industries with one-to-one correspondence to the GTAP sectors (e.g. mining), the calculated implicit carbon tariffs/rebates remain unchanged (and are hence identical across member states for any industry). For GTAP sectors that comprise several WIOD industries, a weighted average tariff (export rebate) is calculated using member states' industry-level imports (exports) as weights. For this reason, for 'composite' GTAP industries comprising more than one WIOD industry, the CBT/export rebates vary across member states. This is usual in empirical work using weighted average tariffs. Also note that because carbon tariffs and export rebates are weighted by imports and exports respectively, the size of the CBT and export rebates differ slightly in the case of composite GTAP sectors.

Table A.4 shows the correspondence between WIOD industries and GTAP sectors.

There is only one WIOD industry that needs to be assigned to two different GTAP sectors: the textiles and apparel industries (C13-C15). The issue is solved by applying the carbon tariff/export rebate calculated at the WIOD industry level to both the 'apparel' and 'textile' GTAP sectors.

Table A.4 / Correspondence between NACE Rev.2 industries and GTAP sectors

WIOD industry code	WIOD industry name	GTAP sector	GTAP ID
A01	Crop and animal production, hunting and related service activities	Agriculture	1
A02	Forestry and logging		
A03	Fishing and aquaculture		
C13-C15	Manufacture of textiles, wearing apparel and leather products	Apparel	2
C20	Manufacture of chemicals and chemical products	Chemical	3
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations		
C22	Manufacture of rubber and plastic products		
C29	Manufacture of motor vehicles, trailers and semi-trailers	Equipment	4
C30	Manufacture of other transport equipment		
C10-C12	Manufacture of food products, beverages and tobacco products	Food	5
C26	Manufacture of computer, electronic and optical products	Machinery	6
C27	Manufacture of electrical equipment		
C28	Manufacture of machinery and equipment n.e.c.		
C24	Manufacture of basic metals	Metal	7
C25	Manufacture of fabricated metal products, except machinery and equipment		
C19	Manufacture of coke and refined petroleum products	Mineral	8
C23	Manufacture of other non-metallic mineral products		
B	Mining and quarrying	Mining	9

contd.

Table A.4 / Continued

WIOD industry code	WIOD industry name	GTAP sector	GTAP ID
D35	Electricity, gas, steam and air conditioning supply	Non-tradables	10
E36	Water collection, treatment and supply		
E37-E39	Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services		
F	Construction		
O84	Public administration and defence; compulsory social security		
P85	Education		
Q	Human health and social work activities		
C31_C32	Manufacture of furniture; other manufacturing	Other	11
C33	Repair and installation of machinery and equipment		
C17	Manufacture of paper and paper products	Paper	12
C18	Printing and reproduction of recorded media		
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	Service	13
G46	Wholesale trade, except of motor vehicles and motorcycles		
G47	Retail trade, except of motor vehicles and motorcycles		
H49	Land transport and transport via pipelines		
H50	Water transport		
H51	Air transport		
H52	Warehousing and support activities for transportation		
H53	Postal and courier activities		
I	Accommodation and food service activities		
J58	Publishing activities		
J59_J60	Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities		
J61	Telecommunications		
J62_J63	Computer programming, consultancy and related activities; information service activities		
K64	Financial service activities, except insurance and pension funding		
K65	Insurance, reinsurance and pension funding, except compulsory social security		
K66	Activities auxiliary to financial services and insurance activities		
L68	Real estate activities		
M69_M70	Legal and accounting activities; activities of head offices; management consultancy activities		
M71	Architectural and engineering activities; technical testing and analysis		
M72	Scientific research and development		
M73	Advertising and market research		
M74_M75	Other professional, scientific and technical activities; veterinary activities		
N	Administrative and support service activities		
R_S	Other service activities		
T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use		
U	Activities of extraterritorial organizations and bodies		
C13-C15	Manufacture of textiles, wearing apparel and leather products	Textile	14
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	Wood	15

A.2.4 Implicit carbon tariffs and export rebates across scenarios

The main text presents the resulting implicit CBT and export rebates for the two main scenarios. Table A.5 shows these tariffs and rebates for Austria and the EU (simple) average across all eight scenarios at the GTAP sector level. The comparison of tariffs within industries across scenarios shows that, in addition to the price assumed in the respective scenario, the free allowances and the sector coverage also matter a lot, at least for some of the important industries such as the minerals sector. This becomes particularly evident when comparing price scenarios 2 and 3. Within each of these scenarios, the carbon price is obviously the same, but resulting tariffs and export rebates differ because of the additional institutional features of the CBA mechanism.

Table A.5 / Implicit carbon tariffs and implicit carbon border rebates in % across all scenarios, 2014

Price scenario:	Scenario 1		Scenario 2		Scenario 2 alternative		Scenario 3		Scenario 3 alternative		Scenario 4	
	ETS current price		ETS future price		ETS future price ex free allowances		IMF carbon tax		IMF carbon tax, full industry coverage		Stiglitz-Stern-Proposal (full industry coverage)	
GTAP sector	**Austria**	**Mean**	**Austria**	**Mean**	**Austria**	**Mean**	**Austria**	**Mean**	**Austria**	**Mean**	**Austria**	**Mean**
Implicit carbon border tariffs												
Agriculture	0.0016	0.0016	0.0029	0.0030	0.0041	0.0042	0.0063	0.0064	1.3250	1.5493	1.7668	2.0660
Apparel	0.0007	0.0007	0.0013	0.0013	0.0020	0.0020	0.0030	0.0030	0.2500	0.2500	0.3333	0.3333
Chemical	0.1494	0.1109	0.2772	0.2058	0.7507	0.5368	1.1429	0.8173	1.1821	0.8688	1.5763	1.1585
Equipment	0.0031	0.0035	0.0057	0.0065	0.0086	0.0106	0.0132	0.0162	0.0844	0.0830	0.1126	0.1107
Food	0.0560	0.0560	0.1039	0.1039	0.1302	0.1302	0.1982	0.1982	0.3177	0.3177	0.4237	0.4237
Machinery	0.0001	0.0000	0.0001	0.0001	0.0002	0.0002	0.0003	0.0003	0.0891	0.0849	0.1188	0.1133
Metal	0.0878	0.0720	0.1628	0.1336	1.1409	0.9361	1.7370	1.4253	1.8167	1.5229	2.4226	2.0308
Mineral	0.1273	0.1288	0.2361	0.2389	2.0107	1.8672	3.0612	2.8427	3.2064	2.9662	4.2757	3.9554
Mining	0.0392	0.0392	0.0726	0.0726	0.2116	0.2116	0.3221	0.3221	1.7911	1.7911	2.3883	2.3883
Non-tradables	0.6455	0.6019	1.1975	1.1165	1.6059	1.4973	2.4450	2.2796	3.1221	2.9164	4.1633	3.8890
Other	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1127	0.1148	0.1503	0.1531
Paper	0.0545	0.0531	0.1010	0.0985	0.5918	0.5400	0.9010	0.8221	1.0473	0.9638	1.3966	1.2852
Service	0.0156	0.0126	0.0290	0.0233	0.0699	0.0563	0.1064	0.0857	0.5604	0.6541	0.7473	0.8723
Textile	0.0007	0.0007	0.0013	0.0013	0.0020	0.0020	0.0030	0.0030	0.2500	0.2500	0.3333	0.3333
Wood	0.0033	0.0033	0.0061	0.0061	0.0119	0.0119	0.0181	0.0181	0.3302	0.3302	0.4403	0.4403
Implicit carbon border rebates												
Agriculture	0.0017	0.0015	0.0031	0.0028	0.0044	0.0039	0.0067	0.0059	1.3346	1.5640	1.7797	2.0856
Apparel	0.0007	0.0007	0.0013	0.0013	0.0020	0.0020	0.0030	0.0030	0.2500	0.2500	0.3333	0.3333
Chemical	0.1490	0.1135	0.2764	0.2106	0.7524	0.5581	1.1456	0.8497	1.1927	0.9135	1.5904	1.2182
Equipment	0.0032	0.0036	0.0059	0.0066	0.0092	0.0111	0.0140	0.0169	0.0840	0.0826	0.1121	0.1102
Food	0.0560	0.0560	0.1039	0.1039	0.1302	0.1302	0.1982	0.1982	0.3177	0.3177	0.4237	0.4237
Machinery	0.0001	0.0000	0.0001	0.0001	0.0002	0.0002	0.0003	0.0003	0.0905	0.0880	0.1207	0.1174
Metal	0.0890	0.0805	0.1651	0.1493	1.1575	1.0466	1.7623	1.5935	1.8405	1.6814	2.4543	2.2422
Mineral	0.1201	0.1222	0.2228	0.2267	2.6928	2.4911	4.0998	3.7926	4.3481	4.0104	5.7981	5.3479
Mining	0.0392	0.0392	0.0726	0.0726	0.2116	0.2116	0.3221	0.3221	1.7911	1.7911	2.3883	2.3883
Non-tradables	1.0613	0.5021	1.9687	0.9315	2.6402	1.2493	4.0197	1.9021	5.1392	2.6506	6.8531	3.5345
Other	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1127	0.1158	0.1503	0.1545
Paper	0.0556	0.0548	0.1030	0.1017	0.6320	0.6044	0.9622	0.9201	1.1120	1.0675	1.4829	1.4235
Service	0.0093	0.0144	0.0172	0.0268	0.0414	0.0646	0.0630	0.0984	0.5243	0.9111	0.6991	1.2149
Textile	0.0007	0.0007	0.0013	0.0013	0.0020	0.0020	0.0030	0.0030	0.2500	0.2500	0.3333	0.3333
Wood	0.0033	0.0033	0.0061	0.0061	0.0119	0.0119	0.0181	0.0181	0.3302	0.3302	0.4403	0.4403

Note: Mean=Simple average of carbon tariff/rebate across EU member states. Scenarios that are highlighted in grey are the main scenarios.

A.3 COMPREHENSIVE QUANTITATIVE RESULTS FOR ALL SCENARIOS

Table A.6 / Trade model results, all scenarios and countries

(a) Exports, change in %

	CBAM limited to carbon tariffs						CBAM including carbon tariffs and export rebates					
	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal
	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)
AUT	0.0053	0.0098	0.0441	0.0666	0.5774	0.7671	0.0450	0.0837	0.3806	0.5888	1.6839	2.2581
BEL	0.0048	0.0089	0.0443	0.0669	0.5834	0.7753	0.0561	0.1043	0.4096	0.6329	1.5476	2.0741
BGR	-0.0005	-0.0009	-0.0027	-0.0038	0.4198	0.5583	0.1306	0.2430	1.3502	2.1254	3.6473	4.9597
CYP	-0.0016	-0.0030	-0.0093	-0.0140	0.4077	0.5422	0.0669	0.1243	0.6437	1.0428	4.8724	6.6635
CZE	0.0059	0.0108	0.0468	0.0706	0.5885	0.7818	0.0463	0.0860	0.4216	0.6539	1.8386	2.4712
DEU	0.0008	0.0016	0.0127	0.0192	0.4637	0.6161	0.0324	0.0603	0.2381	0.3674	1.5965	2.1373
DNK	0.0047	0.0087	0.0414	0.0623	0.4244	0.5664	0.0470	0.0872	0.3065	0.4694	4.0665	5.5317
ESP	-0.0047	-0.0087	-0.0349	-0.0522	0.3739	0.4974	0.0569	0.1058	0.3573	0.5524	1.9587	2.6265
EST	0.0048	0.0089	0.0411	0.0621	0.5397	0.7172	0.0501	0.0930	0.3832	0.5972	2.4322	3.2745
FIN	-0.0032	-0.0059	-0.0330	-0.0494	0.3953	0.5258	0.0907	0.1686	0.7060	1.0990	2.8754	3.8799
FRA	0.0010	0.0019	0.0169	0.0253	0.4763	0.6326	0.0485	0.0902	0.3185	0.4903	1.9203	2.5732
GRC	-0.0060	-0.0111	-0.0404	-0.0612	0.2871	0.3817	0.0595	0.1106	0.4871	0.7658	6.9258	9.5048
HRV	0.0056	0.0104	0.0202	0.0318	0.5286	0.7045	0.0490	0.0911	0.7852	1.2662	3.0047	4.1308
HUN	0.0047	0.0087	0.0419	0.0631	0.5681	0.7544	0.0551	0.1022	0.4183	0.6448	1.8780	2.5183
IRL	0.0045	0.0083	0.0351	0.0533	0.5477	0.7280	0.0580	0.1076	0.3083	0.4742	1.3739	1.8406
ITA	-0.0042	-0.0079	-0.0241	-0.0363	0.3664	0.4871	0.0294	0.0547	0.2381	0.3694	1.4335	1.9208
LTU	0.0025	0.0046	0.0290	0.0436	0.5212	0.6924	0.1078	0.2007	0.6984	1.0780	2.6690	3.5833
LUX	0.0080	0.0149	0.0659	0.0993	0.6533	0.8677	0.0283	0.0525	0.3065	0.4774	1.1837	1.5930
LVA	0.0033	0.0062	0.0296	0.0450	0.5276	0.7014	0.0771	0.1433	0.5505	0.8604	2.7061	3.6572
MLT	0.0049	0.0090	0.0400	0.0602	0.5691	0.7560	0.0286	0.0531	0.1429	0.2177	1.5070	2.0422
NLD	0.0051	0.0095	0.0486	0.0730	0.5548	0.7369	0.0562	0.1046	0.3727	0.5729	1.8244	2.4422
POL	0.0025	0.0047	0.0220	0.0331	0.5098	0.6774	0.0477	0.0886	0.3990	0.6165	1.7100	2.2927
PRT	-0.0014	-0.0026	-0.0026	-0.0042	0.4210	0.5592	0.1099	0.2042	0.6520	1.0024	2.9727	4.0021
ROU	-0.0018	-0.0034	-0.0071	-0.0108	0.3924	0.5216	0.0682	0.1267	0.5917	0.9189	2.5645	3.4499
SVK	0.0060	0.0112	0.0508	0.0766	0.5947	0.7899	0.0457	0.0848	0.4843	0.7514	1.6488	2.2167
SVN	0.0070	0.0129	0.0589	0.0887	0.6112	0.8117	0.0447	0.0830	0.3833	0.5939	2.0115	2.7037
SWE	0.0019	0.0034	0.0149	0.0225	0.4853	0.6448	0.0422	0.0783	0.3386	0.5243	1.7030	2.2832
ALB	-0.0745	-0.1378	-0.5537	-0.8224	-1.9910	-2.6139	-0.0709	-0.1312	-0.5157	-0.7648	-1.8461	-2.4280
ARE	-0.0407	-0.0755	-0.2566	-0.3876	-0.9090	-1.2156	-0.0390	-0.0724	-0.2382	-0.3598	-0.8990	-1.2094
ARG	-0.0191	-0.0354	-0.1044	-0.1575	-0.0990	-0.1326	-0.0180	-0.0334	-0.0920	-0.1384	-0.0860	-0.1165
ARM	-0.0449	-0.0831	-0.2708	-0.4063	-0.6575	-0.8695	-0.0459	-0.0850	-0.2831	-0.4260	-0.6560	-0.8731
AUS	-0.0132	-0.0245	-0.0667	-0.1011	-0.0648	-0.0885	-0.0123	-0.0228	-0.0573	-0.0867	-0.0325	-0.0462
AZE	-0.0810	-0.1502	-0.5325	-0.8039	-2.6087	-3.4741	-0.0817	-0.1514	-0.5250	-0.7933	-2.6213	-3.5083
BGD	-0.0144	-0.0267	-0.0729	-0.1102	-0.0406	-0.0557	-0.0161	-0.0299	-0.0818	-0.1238	-0.0592	-0.0821
BHR	-0.0576	-0.1067	-0.5395	-0.8090	-1.1003	-1.4597	-0.0641	-0.1188	-0.6197	-0.9357	-1.2537	-1.6774
BLR	-0.0965	-0.1785	-0.8504	-1.2624	-1.6284	-2.1308	-0.0911	-0.1685	-0.8061	-1.1969	-1.4188	-1.8599
BOL	-0.0293	-0.0543	-0.1796	-0.2707	-0.4972	-0.6638	-0.0305	-0.0566	-0.1757	-0.2647	-0.5232	-0.7029
BRA	-0.0165	-0.0305	-0.0830	-0.1256	-0.1102	-0.1482	-0.0111	-0.0205	-0.0420	-0.0623	0.0003	-0.0006
BWA	-0.0434	-0.0804	-0.3006	-0.4532	-1.0515	-1.4021	-0.0457	-0.0847	-0.3194	-0.4829	-1.1032	-1.4793
CAN	0.0045	0.0083	0.0407	0.0612	0.5610	0.7453	0.0005	0.0010	0.0183	0.0271	0.4551	0.6055
CHE	0.0095	0.0176	0.0735	0.1106	0.6712	0.8913	0.0103	0.0192	0.0844	0.1279	0.7326	0.9760
CHL	-0.0306	-0.0567	-0.2604	-0.3903	-0.3579	-0.4734	-0.0290	-0.0537	-0.2449	-0.3672	-0.3411	-0.4547
CHN	-0.0088	-0.0163	-0.0436	-0.0660	0.1372	0.1811	-0.0028	-0.0051	0.0107	0.0183	0.2640	0.3522
CIV	-0.0521	-0.0964	-0.3640	-0.5449	-0.8294	-1.0954	-0.0507	-0.0939	-0.3520	-0.5276	-0.7829	-1.0396
CMR	-0.0387	-0.0716	-0.2411	-0.3626	-0.7779	-1.0303	-0.0398	-0.0738	-0.2502	-0.3773	-0.8002	-1.0659
COL	-0.0232	-0.0429	-0.1454	-0.2189	-0.2161	-0.2885	-0.0219	-0.0405	-0.1314	-0.1976	-0.2065	-0.2781
CRI	-0.0203	-0.0375	-0.1074	-0.1617	-0.0590	-0.0787	-0.0211	-0.0392	-0.1080	-0.1629	-0.0869	-0.1178
ECU	-0.0242	-0.0449	-0.1368	-0.2066	-0.3477	-0.4659	-0.0245	-0.0454	-0.1291	-0.1947	-0.3607	-0.4866
EGY	-0.0623	-0.1154	-0.4591	-0.6878	-1.0844	-1.4347	-0.0569	-0.1054	-0.4027	-0.6020	-0.9352	-1.2416
ETH	-0.0244	-0.0452	-0.1493	-0.2240	-0.3818	-0.5057	-0.0246	-0.0456	-0.1454	-0.2180	-0.3457	-0.4605
GBR	0.0090	0.0167	0.0695	0.1048	0.6953	0.9240	0.0070	0.0130	0.0609	0.0919	0.6587	0.8781
GEO	-0.0412	-0.0762	-0.2768	-0.4147	-0.8293	-1.0964	-0.0420	-0.0779	-0.2813	-0.4221	-0.8168	-1.0856

contd.

Table A.6 / Continued

(a) Exports, change in %

	CBAM limited to carbon tariffs						CBAM including carbon tariffs and export rebates					
	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal
	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)
GHA	-0.0348	-0.0644	-0.2709	-0.4052	-0.5172	-0.6821	-0.0353	-0.0653	-0.2718	-0.4075	-0.5132	-0.6816
GTM	-0.0213	-0.0394	-0.1117	-0.1684	-0.0818	-0.1093	-0.0228	-0.0423	-0.1171	-0.1767	-0.1207	-0.1634
HKG	-0.0112	-0.0207	-0.0447	-0.0682	-0.0068	-0.0114	-0.0128	-0.0238	-0.0521	-0.0796	-0.0523	-0.0736
HND	-0.0221	-0.0409	-0.1155	-0.1738	-0.0903	-0.1200	-0.0233	-0.0431	-0.1179	-0.1775	-0.1214	-0.1635
IDN	-0.0161	-0.0298	-0.0837	-0.1267	-0.0221	-0.0313	-0.0128	-0.0237	-0.0473	-0.0702	0.0371	0.0478
IND	-0.0151	-0.0280	-0.0829	-0.1251	-0.0181	-0.0252	-0.0118	-0.0218	-0.0481	-0.0712	0.0532	0.0702
IRN	-0.0437	-0.0810	-0.2763	-0.4172	-1.0989	-1.4675	-0.0378	-0.0700	-0.1924	-0.2874	-0.9551	-1.2808
ISR	-0.0466	-0.0862	-0.2958	-0.4438	-0.5663	-0.7495	-0.0436	-0.0807	-0.2657	-0.3981	-0.4864	-0.6460
JPN	-0.0098	-0.0181	-0.0399	-0.0607	0.0896	0.1172	-0.0063	-0.0116	-0.0109	-0.0159	0.2244	0.2983
KAZ	-0.0375	-0.0696	-0.2765	-0.4158	-0.7606	-1.0138	-0.0367	-0.0681	-0.2624	-0.3948	-0.7389	-0.9909
KEN	-0.0264	-0.0488	-0.1447	-0.2174	-0.1706	-0.2259	-0.0258	-0.0478	-0.1404	-0.2111	-0.1642	-0.2195
KGZ	-0.0303	-0.0562	-0.2817	-0.4212	-0.5257	-0.6933	-0.0323	-0.0599	-0.2980	-0.4469	-0.5613	-0.7461
KHM	-0.0092	-0.0171	-0.0312	-0.0475	0.0560	0.0724	-0.0116	-0.0216	-0.0449	-0.0684	0.0059	0.0038
KOR	0.0040	0.0074	0.0371	0.0558	0.5465	0.7256	-0.0002	-0.0004	0.0110	0.0158	0.4516	0.6000
KWT	-0.0579	-0.1072	-0.4458	-0.6709	-1.4591	-1.9470	-0.0595	-0.1103	-0.4663	-0.7039	-1.5071	-2.0238
LAO	-0.0164	-0.0304	-0.1036	-0.1556	-0.0033	-0.0041	-0.0206	-0.0381	-0.1352	-0.2049	-0.0952	-0.1298
LKA	-0.0191	-0.0355	-0.0927	-0.1400	-0.1094	-0.1468	-0.0201	-0.0372	-0.0899	-0.1356	-0.1171	-0.1585
MAR	-0.1011	-0.1869	-0.6766	-1.0091	-1.4830	-1.9481	-0.0862	-0.1593	-0.5305	-0.7874	-1.1158	-1.4654
MDG	-0.0421	-0.0780	-0.2231	-0.3366	-0.5981	-0.7961	-0.0419	-0.0776	-0.2210	-0.3340	-0.5706	-0.7647
MEX	-0.0132	-0.0244	-0.0609	-0.0923	0.0076	0.0082	-0.0102	-0.0188	-0.0327	-0.0487	0.0433	0.0557
MNG	-0.0193	-0.0358	-0.1275	-0.1923	-0.3083	-0.4133	-0.0216	-0.0400	-0.1388	-0.2097	-0.3566	-0.4813
MOZ	-0.0433	-0.0802	-0.3894	-0.5831	-0.7986	-1.0562	-0.0461	-0.0854	-0.4154	-0.6247	-0.8470	-1.1287
MUS	-0.0271	-0.0501	-0.1414	-0.2136	-0.3534	-0.4729	-0.0286	-0.0530	-0.1463	-0.2213	-0.3787	-0.5101
MWI	-0.0297	-0.0549	-0.1605	-0.2423	-0.5015	-0.6683	-0.0328	-0.0608	-0.1805	-0.2736	-0.5746	-0.7712
MYS	-0.0117	-0.0216	-0.0549	-0.0832	0.1000	0.1313	-0.0126	-0.0234	-0.0547	-0.0827	0.0844	0.1099
NAM	-0.0436	-0.0808	-0.2891	-0.4345	-0.7502	-0.9950	-0.0455	-0.0842	-0.3007	-0.4531	-0.7831	-1.0451
NGA	-0.0726	-0.1346	-0.3987	-0.6053	-2.6443	-3.5147	-0.0719	-0.1333	-0.3840	-0.5833	-2.6367	-3.5188
NIC	-0.0202	-0.0374	-0.1097	-0.1650	-0.1193	-0.1580	-0.0233	-0.0431	-0.1258	-0.1899	-0.1869	-0.2509
NOR	0.0100	0.0185	0.0766	0.1155	0.7633	1.0160	0.0089	0.0165	0.0721	0.1090	0.7614	1.0165
NPL	-0.0180	-0.0334	-0.1146	-0.1725	-0.1932	-0.2568	-0.0203	-0.0377	-0.1291	-0.1951	-0.2303	-0.3093
NZL	0.0042	0.0078	0.0372	0.0560	0.5545	0.7363	0.0005	0.0009	0.0175	0.0258	0.4629	0.6152
OMN	-0.0582	-0.1080	-0.3564	-0.5397	-1.7928	-2.3982	-0.0598	-0.1110	-0.3584	-0.5433	-1.8336	-2.4660
PAK	-0.0159	-0.0295	-0.0863	-0.1301	-0.0684	-0.0919	-0.0165	-0.0305	-0.0816	-0.1225	-0.0629	-0.0855
PAN	-0.0170	-0.0316	-0.0619	-0.0941	-0.1101	-0.1481	-0.0174	-0.0323	-0.0551	-0.0831	-0.1218	-0.1646
PER	-0.0285	-0.0527	-0.2061	-0.3094	-0.2617	-0.3472	-0.0256	-0.0475	-0.1881	-0.2822	-0.2476	-0.3314
PHL	-0.0100	-0.0185	-0.0512	-0.0773	0.1206	0.1591	-0.0096	-0.0177	-0.0410	-0.0614	0.1237	0.1630
PRY	-0.0224	-0.0415	-0.1075	-0.1620	-0.1428	-0.1899	-0.0244	-0.0452	-0.1162	-0.1755	-0.1833	-0.2465
QAT	-0.0491	-0.0910	-0.3160	-0.4774	-1.2115	-1.6211	-0.0524	-0.0971	-0.3383	-0.5124	-1.2669	-1.7050
RUS	-0.0438	-0.0811	-0.3301	-0.4954	-0.8519	-1.1312	-0.0359	-0.0665	-0.2625	-0.3920	-0.6710	-0.8938
SAU	-0.0647	-0.1199	-0.3866	-0.5856	-1.9316	-2.5831	-0.0578	-0.1072	-0.2986	-0.4502	-1.8064	-2.4280
SEN	-0.0485	-0.0897	-0.2856	-0.4277	-0.7393	-0.9762	-0.0458	-0.0848	-0.2526	-0.3773	-0.6644	-0.8801
SGP	-0.0138	-0.0255	-0.0726	-0.1096	0.0763	0.1003	-0.0160	-0.0297	-0.0835	-0.1265	0.0381	0.0482
SLV	-0.0195	-0.0361	-0.1061	-0.1599	-0.0526	-0.0703	-0.0218	-0.0405	-0.1170	-0.1769	-0.1060	-0.1438
THA	-0.0135	-0.0251	-0.0667	-0.1007	0.0852	0.1121	-0.0124	-0.0230	-0.0466	-0.0695	0.1095	0.1445
TUN	-0.1020	-0.1886	-0.6335	-0.9463	-2.0495	-2.6897	-0.0966	-0.1787	-0.5835	-0.8711	-1.8671	-2.4546
TUR	-0.0538	-0.0996	-0.3608	-0.5401	-0.7813	-1.0323	-0.0368	-0.0680	-0.2073	-0.3056	-0.4465	-0.5882
TWN	-0.0116	-0.0215	-0.0636	-0.0960	0.1064	0.1404	-0.0089	-0.0165	-0.0307	-0.0449	0.1554	0.2063
TZA	-0.0286	-0.0529	-0.1858	-0.2793	-0.3789	-0.5026	-0.0312	-0.0578	-0.2029	-0.3061	-0.4211	-0.5635
UGA	-0.0353	-0.0654	-0.2022	-0.3049	-0.6774	-0.9014	-0.0373	-0.0691	-0.2116	-0.3197	-0.7060	-0.9451
UKR	-0.0825	-0.1527	-0.7454	-1.1111	-1.4152	-1.8598	-0.0730	-0.1352	-0.6375	-0.9481	-1.1695	-1.5400
URY	-0.0230	-0.0426	-0.1192	-0.1796	-0.1159	-0.1544	-0.0248	-0.0460	-0.1255	-0.1894	-0.1464	-0.1972
USA	-0.0113	-0.0210	-0.0471	-0.0717	0.0420	0.0539	-0.0069	-0.0128	-0.0144	-0.0211	0.2264	0.3014
VEN	-0.0301	-0.0557	-0.2107	-0.3170	-0.4574	-0.6101	-0.0282	-0.0522	-0.1995	-0.3003	-0.4535	-0.6093
VNM	-0.0135	-0.0250	-0.0608	-0.0921	0.0277	0.0338	-0.0133	-0.0246	-0.0456	-0.0682	0.0349	0.0428

contd.

Table A.6 / Continued

(a) Exports, change in %

	CBAM limited to carbon tariffs						CBAM including carbon tariffs and export rebates					
	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal
	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)
XAC	-0.0759	-0.1408	-0.4169	-0.6332	-2.7825	-3.7017	-0.0745	-0.1382	-0.3993	-0.6067	-2.7797	-3.7136
XCA	-0.0259	-0.0480	-0.1342	-0.2022	-0.0976	-0.1297	-0.0296	-0.0548	-0.1553	-0.2349	-0.1708	-0.2302
XCB	-0.0231	-0.0428	-0.1399	-0.2106	-0.1935	-0.2575	-0.0202	-0.0375	-0.1153	-0.1729	-0.1498	-0.2004
XCF	-0.0701	-0.1300	-0.4162	-0.6291	-2.2125	-2.9343	-0.0670	-0.1242	-0.3855	-0.5825	-2.1611	-2.8771
XEA	-0.0092	-0.0171	-0.0384	-0.0584	0.0819	0.1068	-0.0118	-0.0219	-0.0526	-0.0803	0.0241	0.0286
XEC	-0.0365	-0.0676	-0.2356	-0.3549	-0.7377	-0.9830	-0.0341	-0.0632	-0.2022	-0.3036	-0.6802	-0.9106
XEE	-0.0690	-0.1276	-0.5048	-0.7521	-1.3625	-1.7931	-0.0669	-0.1237	-0.4837	-0.7204	-1.2891	-1.7017
XEF	-0.0750	-0.1388	-0.4860	-0.7256	-1.0311	-1.3569	-0.0695	-0.1286	-0.4380	-0.6529	-0.9001	-1.1862
XER	-0.0852	-0.1576	-0.6549	-0.9743	-1.4402	-1.8900	-0.0739	-0.1367	-0.5414	-0.8028	-1.1827	-1.5537
XNA	-0.0431	-0.0798	-0.2838	-0.4250	-0.5085	-0.6717	-0.0429	-0.0794	-0.2758	-0.4132	-0.4959	-0.6581
XNF	-0.1143	-0.2117	-0.7602	-1.1437	-3.4083	-4.5166	-0.1017	-0.1884	-0.6359	-0.9552	-3.1171	-4.1450
XOC	-0.0223	-0.0413	-0.1622	-0.2438	-0.2071	-0.2754	-0.0222	-0.0411	-0.1533	-0.2303	-0.2132	-0.2859
XSA	-0.0255	-0.0472	-0.1817	-0.2729	-0.3848	-0.5105	-0.0267	-0.0495	-0.1888	-0.2842	-0.4044	-0.5405
XSC	-0.0264	-0.0489	-0.1355	-0.2050	-0.3432	-0.4595	-0.0300	-0.0556	-0.1571	-0.2385	-0.4032	-0.5437
XSE	-0.0157	-0.0292	-0.0803	-0.1218	-0.1411	-0.1918	-0.0177	-0.0328	-0.0893	-0.1356	-0.1814	-0.2482
XSM	-0.0510	-0.0943	-0.4626	-0.6922	-0.7071	-0.9322	-0.0528	-0.0978	-0.4758	-0.7143	-0.7449	-0.9899
XSU	-0.0460	-0.0852	-0.3582	-0.5384	-1.1172	-1.4896	-0.0457	-0.0847	-0.3404	-0.5114	-1.0909	-1.4631
XWF	-0.0609	-0.1127	-0.4121	-0.6188	-1.4091	-1.8622	-0.0575	-0.1066	-0.3815	-0.5730	-1.3427	-1.7817
XWS	-0.0617	-0.1144	-0.3666	-0.5543	-1.7799	-2.3718	-0.0581	-0.1078	-0.3208	-0.4838	-1.6826	-2.2515
ZAF	-0.0298	-0.0552	-0.2075	-0.3116	-0.3354	-0.4447	-0.0226	-0.0419	-0.1601	-0.2391	-0.2325	-0.3088
ZMB	-0.0411	-0.0762	-0.3897	-0.5834	-0.6401	-0.8447	-0.0437	-0.0810	-0.4129	-0.6211	-0.6889	-0.9172
ZWE	-0.0460	-0.0853	-0.4443	-0.6655	-0.8508	-1.1262	-0.0495	-0.0917	-0.4763	-0.7166	-0.9316	-1.2431
EU	0.0005	0.0010	0.0098	0.0148	0.4636	0.6161	0.0468	0.0870	0.3418	0.5288	1.9337	2.5996
Non-EU	-0.0163	-0.0302	-0.0959	-0.1444	-0.0675	-0.0903	-0.0136	-0.0252	-0.0691	-0.1032	0.0104	0.0132
EFTA	0.0074	0.0137	0.0593	0.0896	0.6624	0.8809	0.0075	0.0140	0.0648	0.0985	0.6994	0.9331
World	-0.0104	-0.0192	-0.0585	-0.0881	0.1204	0.1596	0.0078	0.0145	0.0763	0.1204	0.6908	0.9282

Table A.6 / Continued

(b) Real GDP, change in %

	CBAM limited to carbon tariffs						CBAM including carbon tariffs and export rebates					
	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal
	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)
AUT	0.0023	0.0043	0.0172	0.0253	0.0582	0.0759	0.0053	0.0098	0.0434	0.0659	0.1335	0.1777
BEL	0.0028	0.0052	0.0186	0.0274	0.0577	0.0752	0.0070	0.0130	0.0481	0.0731	0.1175	0.1561
BGR	0.0040	0.0075	0.0320	0.0467	0.0972	0.1256	0.0160	0.0297	0.1536	0.2354	0.3700	0.4947
CYP	0.0027	0.0050	0.0170	0.0244	0.0674	0.0863	0.0087	0.0161	0.0751	0.1159	0.5147	0.6913
CZE	0.0023	0.0043	0.0184	0.0271	0.0543	0.0708	0.0052	0.0096	0.0475	0.0723	0.1415	0.1890
DEU	0.0021	0.0039	0.0147	0.0218	0.0514	0.0673	0.0042	0.0077	0.0304	0.0462	0.1228	0.1633
DNK	0.0021	0.0040	0.0133	0.0199	0.0701	0.0879	0.0052	0.0096	0.0313	0.0474	0.4019	0.5372
ESP	0.0028	0.0051	0.0198	0.0293	0.0639	0.0836	0.0077	0.0142	0.0531	0.0806	0.1758	0.2341
EST	0.0023	0.0043	0.0165	0.0239	0.0663	0.0861	0.0057	0.0106	0.0422	0.0640	0.2290	0.3052
FIN	0.0030	0.0055	0.0248	0.0364	0.0678	0.0878	0.0112	0.0208	0.0908	0.1384	0.2738	0.3656
FRA	0.0021	0.0039	0.0135	0.0202	0.0521	0.0685	0.0056	0.0104	0.0357	0.0543	0.1495	0.1994
GRC	0.0035	0.0065	0.0243	0.0359	0.0885	0.1148	0.0090	0.0166	0.0669	0.1018	0.7060	0.9539
HRV	0.0031	0.0057	0.0286	0.0406	0.0853	0.1089	0.0069	0.0127	0.1098	0.1706	0.3281	0.4437
HUN	0.0024	0.0044	0.0174	0.0256	0.0551	0.0719	0.0066	0.0122	0.0482	0.0731	0.1547	0.2061
IRL	0.0024	0.0044	0.0123	0.0177	0.0427	0.0553	0.0072	0.0134	0.0366	0.0551	0.1062	0.1410
ITA	0.0025	0.0046	0.0174	0.0258	0.0598	0.0783	0.0048	0.0089	0.0370	0.0562	0.1247	0.1658
LTU	0.0035	0.0065	0.0240	0.0353	0.0700	0.0909	0.0128	0.0237	0.0795	0.1206	0.2506	0.3333
LUX	0.0019	0.0036	0.0142	0.0209	0.0543	0.0715	0.0028	0.0052	0.0321	0.0492	0.0624	0.0841
LVA	0.0025	0.0046	0.0134	0.0190	0.0543	0.0700	0.0089	0.0166	0.0553	0.0841	0.2367	0.3162
MLT	0.0013	0.0024	0.0068	0.0095	0.0314	0.0402	0.0023	0.0042	0.0063	0.0087	0.0869	0.1166
NLD	0.0025	0.0046	0.0165	0.0247	0.0629	0.0825	0.0068	0.0125	0.0430	0.0655	0.1591	0.2117
POL	0.0028	0.0052	0.0210	0.0311	0.0672	0.0879	0.0062	0.0115	0.0507	0.0770	0.1486	0.1978
PRT	0.0028	0.0052	0.0190	0.0281	0.0688	0.0900	0.0129	0.0239	0.0796	0.1212	0.2868	0.3833
ROU	0.0033	0.0061	0.0231	0.0340	0.0787	0.1026	0.0086	0.0160	0.0670	0.1018	0.2369	0.3155
SVK	0.0028	0.0051	0.0235	0.0346	0.0629	0.0820	0.0057	0.0106	0.0599	0.0913	0.1328	0.1771
SVN	0.0023	0.0042	0.0167	0.0246	0.0542	0.0708	0.0048	0.0089	0.0394	0.0600	0.1591	0.2124
SWE	0.0025	0.0045	0.0185	0.0275	0.0629	0.0823	0.0061	0.0113	0.0491	0.0748	0.1596	0.2125
ALB	-0.0085	-0.0158	-0.0656	-0.0987	-0.2628	-0.3480	-0.0112	-0.0207	-0.0913	-0.1410	-0.3803	-0.5114
ARE	-0.0034	-0.0062	-0.0256	-0.0385	-0.0878	-0.1162	-0.0068	-0.0126	-0.0578	-0.0891	-0.1697	-0.2279
ARG	-0.0015	-0.0028	-0.0089	-0.0135	-0.0388	-0.0514	-0.0033	-0.0061	-0.0209	-0.0323	-0.0861	-0.1158
ARM	-0.0030	-0.0055	-0.0180	-0.0270	-0.0659	-0.0872	-0.0055	-0.0102	-0.0353	-0.0544	-0.1292	-0.1738
AUS	-0.0011	-0.0021	-0.0075	-0.0113	-0.0361	-0.0478	-0.0025	-0.0046	-0.0169	-0.0259	-0.0847	-0.1137
AZE	-0.0049	-0.0091	-0.0388	-0.0583	-0.1439	-0.1903	-0.0082	-0.0152	-0.0743	-0.1154	-0.2396	-0.3229
BGD	-0.0010	-0.0018	-0.0058	-0.0087	-0.0312	-0.0414	-0.0020	-0.0037	-0.0129	-0.0201	-0.0672	-0.0906
BHR	-0.0041	-0.0076	-0.0439	-0.0658	-0.0852	-0.1122	-0.0080	-0.0149	-0.0933	-0.1435	-0.1832	-0.2467
BLR	-0.0068	-0.0126	-0.0625	-0.0936	-0.1441	-0.1900	-0.0091	-0.0170	-0.0841	-0.1283	-0.2173	-0.2909
BOL	-0.0023	-0.0043	-0.0156	-0.0235	-0.0653	-0.0864	-0.0041	-0.0076	-0.0322	-0.0502	-0.1201	-0.1621
BRA	-0.0011	-0.0021	-0.0072	-0.0108	-0.0307	-0.0407	-0.0028	-0.0052	-0.0183	-0.0281	-0.0757	-0.1018
BWA	-0.0031	-0.0058	-0.0243	-0.0366	-0.0929	-0.1229	-0.0053	-0.0099	-0.0441	-0.0680	-0.1548	-0.2078
CAN	0.0003	0.0006	0.0020	0.0031	0.0119	0.0160	-0.0003	-0.0006	-0.0025	-0.0039	-0.0103	-0.0134
CHE	0.0018	0.0034	0.0120	0.0181	0.0422	0.0562	0.0004	0.0007	0.0023	0.0033	0.0019	0.0029
CHL	-0.0030	-0.0056	-0.0266	-0.0399	-0.0724	-0.0957	-0.0057	-0.0107	-0.0501	-0.0768	-0.1446	-0.1942
CHN	-0.0003	-0.0006	-0.0022	-0.0034	-0.0084	-0.0111	-0.0011	-0.0020	-0.0080	-0.0125	-0.0287	-0.0389
CIV	-0.0049	-0.0091	-0.0353	-0.0530	-0.1117	-0.1477	-0.0082	-0.0152	-0.0630	-0.0971	-0.2028	-0.2728
CMR	-0.0034	-0.0063	-0.0222	-0.0335	-0.0938	-0.1242	-0.0061	-0.0113	-0.0433	-0.0669	-0.1750	-0.2354
COL	-0.0019	-0.0035	-0.0137	-0.0206	-0.0457	-0.0604	-0.0039	-0.0073	-0.0292	-0.0450	-0.0966	-0.1298
CRI	-0.0020	-0.0036	-0.0111	-0.0167	-0.0448	-0.0594	-0.0038	-0.0070	-0.0232	-0.0360	-0.0913	-0.1232
ECU	-0.0023	-0.0043	-0.0166	-0.0249	-0.0611	-0.0809	-0.0044	-0.0082	-0.0344	-0.0532	-0.1176	-0.1582
EGY	-0.0044	-0.0082	-0.0345	-0.0518	-0.0986	-0.1303	-0.0077	-0.0143	-0.0659	-0.1020	-0.1876	-0.2531
ETH	-0.0023	-0.0042	-0.0148	-0.0222	-0.0749	-0.0992	-0.0041	-0.0077	-0.0302	-0.0472	-0.1467	-0.1979
GBR	0.0011	0.0020	0.0067	0.0101	0.0322	0.0429	0.0002	0.0003	0.0012	0.0018	0.0033	0.0048
GEO	-0.0034	-0.0063	-0.0240	-0.0361	-0.1013	-0.1340	-0.0058	-0.0108	-0.0434	-0.0673	-0.1826	-0.2460
GHA	-0.0030	-0.0056	-0.0251	-0.0377	-0.0810	-0.1070	-0.0055	-0.0102	-0.0474	-0.0732	-0.1588	-0.2136
GTM	-0.0019	-0.0035	-0.0107	-0.0161	-0.0419	-0.0556	-0.0037	-0.0069	-0.0231	-0.0360	-0.0872	-0.1175

contd.

Table A.6 / Continued

(b) Real GDP, change in %

	CBAM limited to carbon tariffs						CBAM including carbon tariffs and export rebates					
	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal
	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)
HKG	-0.0012	-0.0022	-0.0058	-0.0088	-0.0448	-0.0595	-0.0024	-0.0044	-0.0126	-0.0195	-0.1010	-0.1359
HND	-0.0020	-0.0037	-0.0112	-0.0169	-0.0443	-0.0586	-0.0037	-0.0069	-0.0236	-0.0370	-0.0880	-0.1190
IDN	-0.0012	-0.0023	-0.0083	-0.0125	-0.0292	-0.0387	-0.0030	-0.0055	-0.0219	-0.0338	-0.0707	-0.0954
IND	-0.0009	-0.0018	-0.0065	-0.0098	-0.0226	-0.0299	-0.0025	-0.0046	-0.0187	-0.0289	-0.0641	-0.0864
IRN	-0.0031	-0.0057	-0.0244	-0.0367	-0.0865	-0.1144	-0.0060	-0.0111	-0.0549	-0.0853	-0.1662	-0.2244
ISR	-0.0040	-0.0074	-0.0271	-0.0409	-0.0786	-0.1041	-0.0069	-0.0127	-0.0510	-0.0786	-0.1551	-0.2091
JPN	-0.0005	-0.0009	-0.0028	-0.0043	-0.0136	-0.0181	-0.0014	-0.0026	-0.0087	-0.0135	-0.0462	-0.0624
KAZ	-0.0032	-0.0060	-0.0261	-0.0393	-0.0889	-0.1177	-0.0058	-0.0108	-0.0503	-0.0774	-0.1658	-0.2228
KEN	-0.0023	-0.0042	-0.0128	-0.0193	-0.0458	-0.0606	-0.0048	-0.0089	-0.0297	-0.0461	-0.1020	-0.1377
KGZ	-0.0021	-0.0038	-0.0207	-0.0310	-0.0649	-0.0856	-0.0037	-0.0069	-0.0384	-0.0595	-0.1261	-0.1701
KHM	-0.0007	-0.0014	-0.0034	-0.0051	-0.0290	-0.0385	-0.0014	-0.0027	-0.0081	-0.0131	-0.0579	-0.0786
KOR	0.0004	0.0008	0.0030	0.0045	0.0145	0.0193	-0.0001	-0.0002	-0.0007	-0.0012	-0.0028	-0.0037
KWT	-0.0047	-0.0087	-0.0411	-0.0617	-0.1186	-0.1567	-0.0082	-0.0151	-0.0794	-0.1221	-0.2100	-0.2820
LAO	-0.0019	-0.0034	-0.0136	-0.0204	-0.0435	-0.0575	-0.0035	-0.0064	-0.0271	-0.0418	-0.0896	-0.1206
LKA	-0.0018	-0.0033	-0.0100	-0.0150	-0.0443	-0.0588	-0.0035	-0.0066	-0.0228	-0.0356	-0.0966	-0.1306
MAR	-0.0075	-0.0139	-0.0537	-0.0807	-0.1402	-0.1853	-0.0111	-0.0206	-0.0873	-0.1346	-0.2331	-0.3136
MDG	-0.0033	-0.0062	-0.0198	-0.0298	-0.0716	-0.0948	-0.0062	-0.0114	-0.0389	-0.0602	-0.1340	-0.1802
MEX	-0.0012	-0.0022	-0.0071	-0.0107	-0.0322	-0.0427	-0.0027	-0.0051	-0.0176	-0.0272	-0.0764	-0.1029
MNG	-0.0023	-0.0042	-0.0169	-0.0255	-0.0786	-0.1041	-0.0040	-0.0075	-0.0330	-0.0514	-0.1428	-0.1927
MOZ	-0.0037	-0.0068	-0.0354	-0.0532	-0.0998	-0.1319	-0.0062	-0.0115	-0.0603	-0.0925	-0.1788	-0.2402
MUS	-0.0025	-0.0046	-0.0141	-0.0213	-0.0635	-0.0842	-0.0045	-0.0084	-0.0286	-0.0448	-0.1194	-0.1614
MWI	-0.0033	-0.0061	-0.0201	-0.0304	-0.0952	-0.1262	-0.0061	-0.0114	-0.0408	-0.0633	-0.1773	-0.2385
MYS	-0.0010	-0.0019	-0.0061	-0.0092	-0.0263	-0.0348	-0.0025	-0.0046	-0.0170	-0.0264	-0.0677	-0.0915
NAM	-0.0040	-0.0073	-0.0284	-0.0427	-0.0928	-0.1228	-0.0066	-0.0123	-0.0493	-0.0759	-0.1590	-0.2137
NGA	-0.0045	-0.0083	-0.0331	-0.0499	-0.1365	-0.1806	-0.0075	-0.0140	-0.0626	-0.0965	-0.2222	-0.2985
NIC	-0.0021	-0.0038	-0.0125	-0.0188	-0.0529	-0.0700	-0.0039	-0.0073	-0.0270	-0.0420	-0.1046	-0.1412
NOR	0.0017	0.0032	0.0078	0.0120	0.0849	0.1139	-0.0003	-0.0005	-0.0085	-0.0131	0.0297	0.0409
NPL	-0.0016	-0.0030	-0.0114	-0.0172	-0.0552	-0.0731	-0.0029	-0.0055	-0.0220	-0.0342	-0.1091	-0.1471
NZL	0.0005	0.0009	0.0029	0.0044	0.0167	0.0223	-0.0004	-0.0007	-0.0024	-0.0038	-0.0134	-0.0176
OMN	-0.0042	-0.0077	-0.0330	-0.0497	-0.1182	-0.1563	-0.0073	-0.0135	-0.0651	-0.1007	-0.2005	-0.2696
PAK	-0.0011	-0.0021	-0.0072	-0.0109	-0.0333	-0.0442	-0.0024	-0.0045	-0.0175	-0.0273	-0.0776	-0.1048
PAN	-0.0013	-0.0024	-0.0046	-0.0070	-0.0390	-0.0518	-0.0025	-0.0046	-0.0125	-0.0202	-0.0821	-0.1116
PER	-0.0024	-0.0044	-0.0180	-0.0270	-0.0500	-0.0661	-0.0050	-0.0092	-0.0370	-0.0568	-0.1027	-0.1379
PHL	-0.0007	-0.0013	-0.0048	-0.0072	-0.0179	-0.0238	-0.0018	-0.0033	-0.0128	-0.0200	-0.0501	-0.0680
PRY	-0.0023	-0.0042	-0.0116	-0.0175	-0.0557	-0.0738	-0.0041	-0.0077	-0.0235	-0.0365	-0.1043	-0.1404
QAT	-0.0032	-0.0059	-0.0245	-0.0369	-0.0866	-0.1146	-0.0059	-0.0110	-0.0521	-0.0805	-0.1563	-0.2099
RUS	-0.0030	-0.0056	-0.0250	-0.0376	-0.0790	-0.1045	-0.0054	-0.0101	-0.0457	-0.0700	-0.1450	-0.1946
SAU	-0.0039	-0.0073	-0.0311	-0.0468	-0.1077	-0.1424	-0.0073	-0.0135	-0.0655	-0.1013	-0.1889	-0.2539
SEN	-0.0051	-0.0095	-0.0329	-0.0495	-0.1121	-0.1483	-0.0082	-0.0152	-0.0584	-0.0905	-0.1972	-0.2658
SGP	-0.0010	-0.0019	-0.0067	-0.0101	-0.0202	-0.0267	-0.0026	-0.0049	-0.0186	-0.0288	-0.0647	-0.0874
SLV	-0.0020	-0.0037	-0.0123	-0.0185	-0.0445	-0.0590	-0.0038	-0.0071	-0.0259	-0.0401	-0.0938	-0.1266
THA	-0.0009	-0.0017	-0.0053	-0.0080	-0.0175	-0.0232	-0.0024	-0.0045	-0.0164	-0.0256	-0.0552	-0.0749
TUN	-0.0090	-0.0167	-0.0589	-0.0887	-0.1945	-0.2574	-0.0120	-0.0224	-0.0845	-0.1302	-0.2851	-0.3831
TUR	-0.0049	-0.0091	-0.0358	-0.0539	-0.1007	-0.1333	-0.0091	-0.0169	-0.0724	-0.1118	-0.2055	-0.2771
TWN	-0.0008	-0.0014	-0.0054	-0.0082	-0.0151	-0.0200	-0.0021	-0.0040	-0.0167	-0.0260	-0.0512	-0.0695
TZA	-0.0026	-0.0048	-0.0186	-0.0280	-0.0692	-0.0916	-0.0050	-0.0093	-0.0375	-0.0580	-0.1368	-0.1841
UGA	-0.0029	-0.0054	-0.0190	-0.0286	-0.0799	-0.1058	-0.0054	-0.0100	-0.0384	-0.0595	-0.1496	-0.2014
UKR	-0.0061	-0.0112	-0.0575	-0.0863	-0.1287	-0.1699	-0.0093	-0.0173	-0.0925	-0.1423	-0.2204	-0.2967
URY	-0.0020	-0.0038	-0.0118	-0.0177	-0.0442	-0.0586	-0.0039	-0.0073	-0.0246	-0.0380	-0.0931	-0.1253
USA	-0.0004	-0.0008	-0.0021	-0.0032	-0.0126	-0.0167	-0.0011	-0.0020	-0.0060	-0.0093	-0.0391	-0.0526
VEN	-0.0025	-0.0047	-0.0202	-0.0304	-0.0613	-0.0810	-0.0048	-0.0089	-0.0391	-0.0599	-0.1168	-0.1565
VNM	-0.0012	-0.0022	-0.0073	-0.0111	-0.0317	-0.0420	-0.0025	-0.0047	-0.0186	-0.0293	-0.0656	-0.0891

contd.

Table A.6 / Continued

(b) Real GDP, change in %

	CBAM limited to carbon tariffs						CBAM including carbon tariffs and export rebates					
	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal
	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)
XAC	-0.0052	-0.0097	-0.0381	-0.0574	-0.1606	-0.2125	-0.0088	-0.0164	-0.0723	-0.1113	-0.2584	-0.3463
XCA	-0.0029	-0.0054	-0.0162	-0.0244	-0.0546	-0.0723	-0.0052	-0.0096	-0.0309	-0.0478	-0.1033	-0.1391
XCB	-0.0019	-0.0036	-0.0130	-0.0195	-0.0458	-0.0606	-0.0039	-0.0072	-0.0263	-0.0405	-0.0970	-0.1304
XCF	-0.0047	-0.0087	-0.0340	-0.0512	-0.1355	-0.1794	-0.0081	-0.0150	-0.0649	-0.1001	-0.2264	-0.3041
XEA	-0.0008	-0.0015	-0.0038	-0.0058	-0.0323	-0.0430	-0.0015	-0.0028	-0.0071	-0.0111	-0.0696	-0.0938
XEC	-0.0030	-0.0055	-0.0219	-0.0329	-0.0781	-0.1033	-0.0056	-0.0104	-0.0467	-0.0723	-0.1510	-0.2035
XEE	-0.0064	-0.0119	-0.0476	-0.0716	-0.1686	-0.2232	-0.0094	-0.0175	-0.0731	-0.1131	-0.2599	-0.3495
XEF	-0.0072	-0.0133	-0.0485	-0.0730	-0.1296	-0.1714	-0.0096	-0.0178	-0.0685	-0.1052	-0.1963	-0.2638
XER	-0.0081	-0.0150	-0.0651	-0.0978	-0.1645	-0.2173	-0.0116	-0.0216	-0.0986	-0.1515	-0.2602	-0.3498
XNA	-0.0039	-0.0072	-0.0261	-0.0392	-0.0786	-0.1040	-0.0056	-0.0103	-0.0387	-0.0594	-0.1284	-0.1722
XNF	-0.0066	-0.0122	-0.0512	-0.0770	-0.1782	-0.2358	-0.0107	-0.0198	-0.0919	-0.1414	-0.2873	-0.3855
XOC	-0.0023	-0.0043	-0.0189	-0.0284	-0.0610	-0.0807	-0.0043	-0.0080	-0.0360	-0.0553	-0.1206	-0.1621
XSA	-0.0024	-0.0044	-0.0180	-0.0271	-0.0723	-0.0957	-0.0041	-0.0076	-0.0329	-0.0509	-0.1362	-0.1833
XSC	-0.0026	-0.0048	-0.0148	-0.0223	-0.0638	-0.0845	-0.0049	-0.0091	-0.0303	-0.0468	-0.1224	-0.1648
XSE	-0.0024	-0.0044	-0.0172	-0.0259	-0.0681	-0.0902	-0.0043	-0.0080	-0.0349	-0.0538	-0.1293	-0.1739
XSM	-0.0044	-0.0081	-0.0421	-0.0631	-0.0915	-0.1208	-0.0070	-0.0130	-0.0678	-0.1038	-0.1559	-0.2092
XSU	-0.0028	-0.0053	-0.0240	-0.0360	-0.0882	-0.1166	-0.0049	-0.0091	-0.0461	-0.0715	-0.1560	-0.2104
XWF	-0.0047	-0.0088	-0.0352	-0.0530	-0.1268	-0.1678	-0.0079	-0.0147	-0.0624	-0.0963	-0.2137	-0.2870
XWS	-0.0039	-0.0073	-0.0255	-0.0384	-0.1224	-0.1622	-0.0071	-0.0132	-0.0552	-0.0865	-0.2196	-0.2966
ZAF	-0.0028	-0.0051	-0.0209	-0.0315	-0.0600	-0.0794	-0.0055	-0.0102	-0.0412	-0.0631	-0.1237	-0.1661
ZMB	-0.0037	-0.0068	-0.0356	-0.0534	-0.0916	-0.1209	-0.0065	-0.0120	-0.0644	-0.0989	-0.1737	-0.2335
ZWE	-0.0034	-0.0063	-0.0368	-0.0552	-0.0870	-0.1147	-0.0059	-0.0110	-0.0661	-0.1018	-0.1579	-0.2124
EU	0.0024	0.0045	0.0168	0.0249	0.0583	0.0762	0.0059	0.0109	0.0424	0.0645	0.1630	0.2174
Non-EU	-0.0008	-0.0015	-0.0060	-0.0090	-0.0209	-0.0276	-0.0020	-0.0038	-0.0150	-0.0232	-0.0576	-0.0776
EFTA	0.0015	0.0028	0.0084	0.0127	0.0559	0.0748	-0.0002	-0.0004	-0.0045	-0.0071	0.0082	0.0117
World	0.0000	0.0000	-0.0001	-0.0003	-0.0006	-0.0010	0.0000	0.0000	-0.0003	-0.0007	-0.0011	-0.0020

Table A.6 / Continued

(c) Welfare, change in %

	CBAM limited to carbon tariffs						CBAM including carbon tariffs and export rebates					
	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal
	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)
AUT	0.0024	0.0044	0.0180	0.0265	0.0592	0.0772	0.0054	0.0099	0.0446	0.0678	0.1352	0.1799
BEL	0.0029	0.0053	0.0193	0.0285	0.0587	0.0765	0.0071	0.0132	0.0493	0.0750	0.1191	0.1583
BGR	0.0041	0.0075	0.0322	0.0470	0.0974	0.1259	0.0160	0.0297	0.1539	0.2359	0.3704	0.4953
CYP	0.0028	0.0051	0.0176	0.0253	0.0683	0.0874	0.0088	0.0163	0.0762	0.1175	0.5162	0.6932
CZE	0.0023	0.0043	0.0186	0.0274	0.0546	0.0711	0.0052	0.0097	0.0478	0.0728	0.1419	0.1895
DEU	0.0022	0.0040	0.0154	0.0229	0.0524	0.0686	0.0043	0.0079	0.0317	0.0480	0.1244	0.1655
DNK	0.0022	0.0041	0.0141	0.0210	0.0711	0.0892	0.0053	0.0098	0.0325	0.0492	0.4035	0.5395
ESP	0.0028	0.0052	0.0205	0.0304	0.0649	0.0849	0.0078	0.0144	0.0543	0.0825	0.1774	0.2363
EST	0.0024	0.0044	0.0167	0.0242	0.0666	0.0864	0.0057	0.0106	0.0425	0.0645	0.2294	0.3057
FIN	0.0030	0.0056	0.0256	0.0375	0.0688	0.0891	0.0113	0.0210	0.0921	0.1403	0.2754	0.3678
FRA	0.0022	0.0040	0.0143	0.0213	0.0531	0.0698	0.0057	0.0106	0.0369	0.0562	0.1512	0.2016
GRC	0.0036	0.0066	0.0251	0.0370	0.0895	0.1160	0.0091	0.0168	0.0681	0.1037	0.7077	0.9562
HRV	0.0031	0.0058	0.0288	0.0408	0.0856	0.1092	0.0069	0.0128	0.1101	0.1710	0.3285	0.4442
HUN	0.0024	0.0045	0.0176	0.0259	0.0554	0.0722	0.0066	0.0123	0.0485	0.0735	0.1551	0.2066
IRL	0.0024	0.0045	0.0130	0.0188	0.0437	0.0565	0.0073	0.0136	0.0378	0.0570	0.1078	0.1432
ITA	0.0026	0.0047	0.0181	0.0269	0.0608	0.0796	0.0049	0.0091	0.0382	0.0581	0.1263	0.1680
LTU	0.0036	0.0066	0.0242	0.0355	0.0703	0.0912	0.0128	0.0237	0.0798	0.1211	0.2510	0.3339
LUX	0.0020	0.0037	0.0149	0.0220	0.0553	0.0728	0.0029	0.0054	0.0333	0.0511	0.0640	0.0863
LVA	0.0025	0.0046	0.0136	0.0193	0.0545	0.0703	0.0090	0.0166	0.0556	0.0846	0.2372	0.3168
MLT	0.0014	0.0025	0.0074	0.0104	0.0322	0.0414	0.0024	0.0044	0.0074	0.0103	0.0883	0.1186
NLD	0.0026	0.0047	0.0172	0.0258	0.0639	0.0838	0.0069	0.0127	0.0442	0.0673	0.1607	0.2139
POL	0.0028	0.0052	0.0212	0.0313	0.0674	0.0882	0.0062	0.0116	0.0510	0.0775	0.1490	0.1983
PRT	0.0029	0.0053	0.0197	0.0292	0.0698	0.0912	0.0130	0.0241	0.0808	0.1231	0.2885	0.3855
ROU	0.0033	0.0061	0.0233	0.0343	0.0789	0.1029	0.0086	0.0160	0.0673	0.1023	0.2373	0.3161
SVK	0.0028	0.0052	0.0237	0.0349	0.0631	0.0823	0.0057	0.0106	0.0603	0.0917	0.1332	0.1776
SVN	0.0023	0.0042	0.0169	0.0248	0.0545	0.0712	0.0048	0.0090	0.0397	0.0604	0.1595	0.2129
SWE	0.0025	0.0047	0.0193	0.0286	0.0639	0.0835	0.0062	0.0115	0.0504	0.0767	0.1613	0.2147
ALB	-0.0084	-0.0157	-0.0649	-0.0976	-0.2619	-0.3468	-0.0111	-0.0205	-0.0902	-0.1393	-0.3788	-0.5094
ARE	-0.0033	-0.0062	-0.0250	-0.0377	-0.0872	-0.1153	-0.0067	-0.0125	-0.0569	-0.0878	-0.1685	-0.2264
ARG	-0.0014	-0.0027	-0.0083	-0.0125	-0.0380	-0.0503	-0.0032	-0.0059	-0.0199	-0.0307	-0.0847	-0.1139
ARM	-0.0029	-0.0054	-0.0173	-0.0260	-0.0650	-0.0860	-0.0054	-0.0100	-0.0341	-0.0527	-0.1277	-0.1717
AUS	-0.0011	-0.0021	-0.0075	-0.0113	-0.0361	-0.0478	-0.0025	-0.0046	-0.0169	-0.0259	-0.0847	-0.1137
AZE	-0.0048	-0.0090	-0.0381	-0.0573	-0.1430	-0.1891	-0.0081	-0.0150	-0.0732	-0.1136	-0.2381	-0.3209
BGD	-0.0009	-0.0017	-0.0051	-0.0077	-0.0303	-0.0402	-0.0019	-0.0035	-0.0118	-0.0184	-0.0656	-0.0886
BHR	-0.0041	-0.0076	-0.0434	-0.0651	-0.0845	-0.1113	-0.0079	-0.0147	-0.0924	-0.1422	-0.1821	-0.2452
BLR	-0.0068	-0.0126	-0.0623	-0.0934	-0.1439	-0.1896	-0.0091	-0.0169	-0.0838	-0.1279	-0.2169	-0.2904
BOL	-0.0023	-0.0042	-0.0149	-0.0225	-0.0644	-0.0852	-0.0040	-0.0075	-0.0310	-0.0484	-0.1185	-0.1600
BRA	-0.0011	-0.0020	-0.0065	-0.0099	-0.0298	-0.0396	-0.0027	-0.0050	-0.0172	-0.0265	-0.0742	-0.0999
BWA	-0.0030	-0.0056	-0.0232	-0.0350	-0.0915	-0.1212	-0.0052	-0.0096	-0.0424	-0.0654	-0.1524	-0.2047
CAN	0.0003	0.0006	0.0020	0.0031	0.0119	0.0160	-0.0003	-0.0006	-0.0025	-0.0039	-0.0103	-0.0134
CHE	0.0019	0.0035	0.0127	0.0192	0.0432	0.0575	0.0005	0.0009	0.0035	0.0052	0.0035	0.0051
CHL	-0.0030	-0.0055	-0.0261	-0.0392	-0.0718	-0.0949	-0.0057	-0.0106	-0.0493	-0.0756	-0.1436	-0.1928
CHN	-0.0003	-0.0006	-0.0022	-0.0033	-0.0083	-0.0110	-0.0011	-0.0020	-0.0079	-0.0124	-0.0286	-0.0387
CIV	-0.0048	-0.0089	-0.0343	-0.0515	-0.1103	-0.1459	-0.0080	-0.0149	-0.0613	-0.0945	-0.2005	-0.2697
CMR	-0.0033	-0.0062	-0.0212	-0.0319	-0.0925	-0.1225	-0.0059	-0.0110	-0.0416	-0.0644	-0.1727	-0.2323
COL	-0.0018	-0.0034	-0.0132	-0.0199	-0.0450	-0.0596	-0.0038	-0.0072	-0.0285	-0.0438	-0.0955	-0.1284
CRI	-0.0019	-0.0036	-0.0106	-0.0160	-0.0442	-0.0585	-0.0037	-0.0069	-0.0224	-0.0349	-0.0902	-0.1218
ECU	-0.0023	-0.0042	-0.0161	-0.0242	-0.0605	-0.0801	-0.0043	-0.0081	-0.0336	-0.0520	-0.1165	-0.1568
EGY	-0.0044	-0.0081	-0.0334	-0.0502	-0.0972	-0.1285	-0.0076	-0.0140	-0.0642	-0.0994	-0.1853	-0.2500
ETH	-0.0022	-0.0040	-0.0137	-0.0207	-0.0736	-0.0974	-0.0040	-0.0074	-0.0285	-0.0447	-0.1444	-0.1949
GBR	0.0011	0.0021	0.0074	0.0112	0.0332	0.0442	0.0003	0.0005	0.0025	0.0037	0.0050	0.0070
GEO	-0.0034	-0.0062	-0.0233	-0.0350	-0.1004	-0.1328	-0.0057	-0.0106	-0.0422	-0.0655	-0.1811	-0.2439
GHA	-0.0029	-0.0055	-0.0240	-0.0361	-0.0796	-0.1053	-0.0054	-0.0099	-0.0457	-0.0706	-0.1565	-0.2106
GTM	-0.0018	-0.0034	-0.0100	-0.0151	-0.0410	-0.0544	-0.0036	-0.0068	-0.0220	-0.0342	-0.0856	-0.1155

contd.

Table A.6 / Continued

(c) Welfare, change in %

	CBAM limited to carbon tariffs						CBAM including carbon tariffs and export rebates					
	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal
	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)
HKG	-0.0012	-0.0022	-0.0058	-0.0088	-0.0448	-0.0595	-0.0024	-0.0044	-0.0126	-0.0195	-0.1010	-0.1359
HND	-0.0019	-0.0035	-0.0105	-0.0159	-0.0433	-0.0574	-0.0036	-0.0067	-0.0225	-0.0352	-0.0864	-0.1169
IDN	-0.0012	-0.0022	-0.0076	-0.0115	-0.0283	-0.0375	-0.0029	-0.0054	-0.0207	-0.0321	-0.0691	-0.0933
IND	-0.0008	-0.0015	-0.0052	-0.0079	-0.0208	-0.0276	-0.0023	-0.0043	-0.0165	-0.0256	-0.0611	-0.0826
IRN	-0.0031	-0.0057	-0.0239	-0.0360	-0.0859	-0.1136	-0.0059	-0.0110	-0.0541	-0.0841	-0.1652	-0.2230
ISR	-0.0040	-0.0074	-0.0271	-0.0409	-0.0786	-0.1041	-0.0069	-0.0127	-0.0510	-0.0786	-0.1551	-0.2091
JPN	-0.0005	-0.0009	-0.0027	-0.0041	-0.0134	-0.0179	-0.0014	-0.0025	-0.0085	-0.0131	-0.0460	-0.0620
KAZ	-0.0032	-0.0059	-0.0257	-0.0386	-0.0883	-0.1169	-0.0057	-0.0107	-0.0495	-0.0762	-0.1647	-0.2214
KEN	-0.0022	-0.0040	-0.0118	-0.0178	-0.0445	-0.0589	-0.0046	-0.0086	-0.0280	-0.0435	-0.0997	-0.1346
KGZ	-0.0020	-0.0037	-0.0200	-0.0300	-0.0639	-0.0844	-0.0036	-0.0068	-0.0372	-0.0578	-0.1245	-0.1681
KHM	-0.0007	-0.0013	-0.0027	-0.0041	-0.0280	-0.0373	-0.0013	-0.0025	-0.0070	-0.0114	-0.0563	-0.0766
KOR	0.0005	0.0009	0.0036	0.0055	0.0154	0.0204	0.0000	-0.0001	0.0003	0.0004	-0.0014	-0.0018
KWT	-0.0046	-0.0086	-0.0406	-0.0609	-0.1180	-0.1558	-0.0081	-0.0150	-0.0786	-0.1208	-0.2089	-0.2804
LAO	-0.0018	-0.0033	-0.0129	-0.0194	-0.0426	-0.0563	-0.0034	-0.0062	-0.0260	-0.0400	-0.0881	-0.1185
LKA	-0.0017	-0.0032	-0.0093	-0.0140	-0.0434	-0.0576	-0.0034	-0.0064	-0.0216	-0.0338	-0.0950	-0.1285
MAR	-0.0074	-0.0137	-0.0526	-0.0791	-0.1389	-0.1835	-0.0110	-0.0203	-0.0856	-0.1320	-0.2308	-0.3105
MDG	-0.0033	-0.0060	-0.0187	-0.0283	-0.0702	-0.0930	-0.0060	-0.0112	-0.0372	-0.0576	-0.1317	-0.1771
MEX	-0.0012	-0.0022	-0.0066	-0.0100	-0.0315	-0.0419	-0.0027	-0.0050	-0.0168	-0.0260	-0.0753	-0.1015
MNG	-0.0022	-0.0041	-0.0162	-0.0245	-0.0777	-0.1029	-0.0039	-0.0073	-0.0318	-0.0497	-0.1413	-0.1907
MOZ	-0.0036	-0.0067	-0.0344	-0.0517	-0.0985	-0.1301	-0.0061	-0.0113	-0.0586	-0.0899	-0.1765	-0.2371
MUS	-0.0024	-0.0044	-0.0131	-0.0198	-0.0621	-0.0824	-0.0044	-0.0081	-0.0269	-0.0422	-0.1171	-0.1583
MWI	-0.0032	-0.0059	-0.0191	-0.0288	-0.0939	-0.1244	-0.0060	-0.0111	-0.0391	-0.0607	-0.1750	-0.2354
MYS	-0.0010	-0.0018	-0.0055	-0.0083	-0.0254	-0.0337	-0.0024	-0.0044	-0.0159	-0.0248	-0.0663	-0.0896
NAM	-0.0039	-0.0072	-0.0273	-0.0412	-0.0915	-0.1210	-0.0065	-0.0120	-0.0475	-0.0733	-0.1567	-0.2106
NGA	-0.0044	-0.0082	-0.0321	-0.0483	-0.1351	-0.1789	-0.0074	-0.0137	-0.0609	-0.0940	-0.2199	-0.2954
NIC	-0.0020	-0.0037	-0.0118	-0.0177	-0.0519	-0.0688	-0.0038	-0.0071	-0.0258	-0.0403	-0.1030	-0.1391
NOR	0.0018	0.0033	0.0086	0.0132	0.0859	0.1152	-0.0002	-0.0003	-0.0073	-0.0113	0.0314	0.0431
NPL	-0.0016	-0.0029	-0.0107	-0.0162	-0.0542	-0.0719	-0.0028	-0.0053	-0.0209	-0.0324	-0.1076	-0.1450
NZL	0.0005	0.0009	0.0029	0.0044	0.0167	0.0223	-0.0004	-0.0007	-0.0024	-0.0038	-0.0134	-0.0176
OMN	-0.0041	-0.0076	-0.0325	-0.0489	-0.1175	-0.1554	-0.0072	-0.0133	-0.0643	-0.0994	-0.1994	-0.2681
PAK	-0.0011	-0.0020	-0.0066	-0.0099	-0.0324	-0.0430	-0.0023	-0.0043	-0.0163	-0.0255	-0.0760	-0.1028
PAN	-0.0012	-0.0023	-0.0041	-0.0063	-0.0383	-0.0509	-0.0024	-0.0044	-0.0117	-0.0190	-0.0811	-0.1101
PER	-0.0023	-0.0043	-0.0175	-0.0263	-0.0494	-0.0653	-0.0049	-0.0091	-0.0362	-0.0556	-0.1016	-0.1364
PHL	-0.0007	-0.0012	-0.0041	-0.0061	-0.0170	-0.0226	-0.0017	-0.0031	-0.0116	-0.0182	-0.0486	-0.0659
PRY	-0.0022	-0.0041	-0.0111	-0.0168	-0.0551	-0.0730	-0.0041	-0.0076	-0.0227	-0.0353	-0.1033	-0.1389
QAT	-0.0031	-0.0058	-0.0240	-0.0362	-0.0860	-0.1137	-0.0059	-0.0109	-0.0512	-0.0792	-0.1551	-0.2084
RUS	-0.0030	-0.0056	-0.0250	-0.0376	-0.0790	-0.1045	-0.0054	-0.0101	-0.0457	-0.0700	-0.1450	-0.1946
SAU	-0.0039	-0.0072	-0.0306	-0.0461	-0.1071	-0.1416	-0.0072	-0.0134	-0.0647	-0.1000	-0.1877	-0.2524
SEN	-0.0050	-0.0093	-0.0319	-0.0480	-0.1108	-0.1466	-0.0080	-0.0149	-0.0567	-0.0879	-0.1949	-0.2627
SGP	-0.0010	-0.0019	-0.0067	-0.0101	-0.0202	-0.0267	-0.0026	-0.0049	-0.0186	-0.0288	-0.0647	-0.0874
SLV	-0.0019	-0.0036	-0.0118	-0.0178	-0.0439	-0.0582	-0.0038	-0.0070	-0.0251	-0.0389	-0.0928	-0.1252
THA	-0.0009	-0.0016	-0.0048	-0.0073	-0.0169	-0.0224	-0.0023	-0.0044	-0.0157	-0.0244	-0.0541	-0.0734
TUN	-0.0089	-0.0166	-0.0579	-0.0872	-0.1931	-0.2556	-0.0119	-0.0221	-0.0828	-0.1277	-0.2828	-0.3800
TUR	-0.0049	-0.0091	-0.0354	-0.0532	-0.1001	-0.1324	-0.0090	-0.0168	-0.0716	-0.1106	-0.2045	-0.2757
TWN	-0.0007	-0.0013	-0.0048	-0.0072	-0.0143	-0.0189	-0.0021	-0.0038	-0.0156	-0.0244	-0.0498	-0.0676
TZA	-0.0025	-0.0047	-0.0176	-0.0265	-0.0678	-0.0898	-0.0049	-0.0091	-0.0358	-0.0554	-0.1345	-0.1811
UGA	-0.0028	-0.0052	-0.0180	-0.0271	-0.0786	-0.1040	-0.0052	-0.0097	-0.0367	-0.0569	-0.1473	-0.1983
UKR	-0.0061	-0.0112	-0.0573	-0.0860	-0.1285	-0.1696	-0.0093	-0.0173	-0.0922	-0.1418	-0.2200	-0.2962
URY	-0.0020	-0.0037	-0.0113	-0.0170	-0.0436	-0.0578	-0.0039	-0.0072	-0.0238	-0.0368	-0.0920	-0.1239
USA	-0.0004	-0.0007	-0.0020	-0.0031	-0.0124	-0.0165	-0.0011	-0.0020	-0.0058	-0.0090	-0.0388	-0.0523
VEN	-0.0025	-0.0046	-0.0197	-0.0296	-0.0606	-0.0802	-0.0047	-0.0088	-0.0383	-0.0587	-0.1157	-0.1551
VNM	-0.0011	-0.0021	-0.0066	-0.0100	-0.0308	-0.0408	-0.0024	-0.0045	-0.0174	-0.0276	-0.0641	-0.0871

contd.

Table A.6 / Continued

(c) Welfare, change in %

	CBAM limited to carbon tariffs						CBAM including carbon tariffs and export rebates					
	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal
	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)
XAC	-0.0051	-0.0095	-0.0371	-0.0559	-0.1592	-0.2108	-0.0087	-0.0161	-0.0706	-0.1087	-0.2560	-0.3433
XCA	-0.0029	-0.0053	-0.0157	-0.0237	-0.0539	-0.0714	-0.0051	-0.0095	-0.0301	-0.0466	-0.1022	-0.1376
XCB	-0.0019	-0.0035	-0.0123	-0.0186	-0.0449	-0.0595	-0.0038	-0.0070	-0.0253	-0.0389	-0.0956	-0.1285
XCF	-0.0046	-0.0086	-0.0330	-0.0497	-0.1342	-0.1776	-0.0079	-0.0147	-0.0632	-0.0975	-0.2241	-0.3010
XEA	-0.0008	-0.0014	-0.0031	-0.0048	-0.0315	-0.0419	-0.0014	-0.0026	-0.0061	-0.0095	-0.0682	-0.0919
XEC	-0.0029	-0.0053	-0.0209	-0.0314	-0.0767	-0.1015	-0.0054	-0.0101	-0.0450	-0.0697	-0.1487	-0.2004
XEE	-0.0064	-0.0119	-0.0474	-0.0714	-0.1683	-0.2228	-0.0094	-0.0174	-0.0728	-0.1126	-0.2595	-0.3490
XEF	-0.0071	-0.0132	-0.0478	-0.0719	-0.1286	-0.1701	-0.0095	-0.0176	-0.0673	-0.1034	-0.1947	-0.2615
XER	-0.0081	-0.0149	-0.0644	-0.0968	-0.1636	-0.2162	-0.0115	-0.0214	-0.0975	-0.1499	-0.2588	-0.3479
XNA	-0.0038	-0.0070	-0.0253	-0.0381	-0.0776	-0.1027	-0.0054	-0.0101	-0.0375	-0.0575	-0.1268	-0.1700
XNF	-0.0065	-0.0120	-0.0502	-0.0755	-0.1769	-0.2340	-0.0105	-0.0195	-0.0902	-0.1388	-0.2850	-0.3824
XOC	-0.0023	-0.0042	-0.0184	-0.0277	-0.0604	-0.0799	-0.0042	-0.0078	-0.0352	-0.0541	-0.1196	-0.1607
XSA	-0.0023	-0.0043	-0.0173	-0.0261	-0.0714	-0.0945	-0.0040	-0.0074	-0.0318	-0.0492	-0.1346	-0.1812
XSC	-0.0025	-0.0046	-0.0138	-0.0208	-0.0624	-0.0827	-0.0048	-0.0089	-0.0286	-0.0442	-0.1201	-0.1617
XSE	-0.0023	-0.0042	-0.0166	-0.0250	-0.0673	-0.0891	-0.0042	-0.0078	-0.0338	-0.0522	-0.1278	-0.1720
XSM	-0.0043	-0.0080	-0.0416	-0.0624	-0.0909	-0.1200	-0.0069	-0.0128	-0.0670	-0.1026	-0.1548	-0.2078
XSU	-0.0028	-0.0051	-0.0233	-0.0350	-0.0873	-0.1155	-0.0048	-0.0089	-0.0449	-0.0697	-0.1545	-0.2084
XWF	-0.0046	-0.0086	-0.0342	-0.0515	-0.1254	-0.1660	-0.0078	-0.0145	-0.0607	-0.0937	-0.2114	-0.2839
XWS	-0.0039	-0.0072	-0.0248	-0.0374	-0.1215	-0.1610	-0.0070	-0.0130	-0.0541	-0.0848	-0.2181	-0.2946
ZAF	-0.0027	-0.0049	-0.0199	-0.0299	-0.0586	-0.0776	-0.0054	-0.0100	-0.0395	-0.0605	-0.1214	-0.1631
ZMB	-0.0036	-0.0067	-0.0346	-0.0519	-0.0902	-0.1192	-0.0063	-0.0118	-0.0627	-0.0963	-0.1714	-0.2304
ZWE	-0.0033	-0.0062	-0.0358	-0.0537	-0.0856	-0.1129	-0.0058	-0.0108	-0.0644	-0.0992	-0.1556	-0.2093
EU	0.0025	0.0046	0.0175	0.0259	0.0593	0.0774	0.0060	0.0111	0.0435	0.0662	0.1645	0.2194
Non-EU	-0.0008	-0.0015	-0.0056	-0.0085	-0.0205	-0.0271	-0.0020	-0.0037	-0.0145	-0.0224	-0.0569	-0.0766
EFTA	0.0016	0.0030	0.0091	0.0139	0.0569	0.0761	-0.0001	-0.0002	-0.0033	-0.0052	0.0099	0.0139
World	0.0000	0.0001	0.0003	0.0003	0.0000	-0.0003	0.0001	0.0001	0.0004	0.0003	-0.0002	-0.0008

Table A.6 / Continued

(d) CO_2 emissions, change in %

	CBAM limited to carbon tariffs						CBAM including carbon tariffs and export rebates					
	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal
	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)
AUT	0.0120	0.0223	0.1548	0.2323	0.2490	0.3278	0.0306	0.0569	0.5153	0.7984	0.8629	1.1705
BEL	0.0139	0.0257	0.1633	0.2450	0.2198	0.2886	0.0362	0.0672	0.3823	0.5830	0.5773	0.7710
BGR	0.0182	0.0337	0.2187	0.3297	0.3104	0.4102	0.0665	0.1234	1.0268	1.5802	1.5336	2.0677
CYP	0.0006	0.0011	0.0152	0.0231	0.0390	0.0522	-0.0028	-0.0052	0.3510	0.5679	1.0634	1.4651
CZE	0.0166	0.0307	0.1852	0.2781	0.3378	0.4457	0.0391	0.0726	0.6638	1.0336	1.1725	1.5977
DEU	0.0176	0.0326	0.1764	0.2649	0.2804	0.3694	0.0404	0.0749	0.4439	0.6817	0.6869	0.9238
DNK	0.0089	0.0165	0.1211	0.1817	0.2094	0.2752	0.0220	0.0409	0.3355	0.5155	0.8694	1.1654
ESP	0.0141	0.0260	0.1519	0.2283	0.2414	0.3182	0.0319	0.0592	0.3910	0.5992	0.5949	0.7978
EST	0.0033	0.0061	0.0305	0.0458	0.1005	0.1332	0.0106	0.0196	0.1855	0.2906	0.5696	0.7711
FIN	0.0220	0.0407	0.2541	0.3827	0.3966	0.5237	0.0593	0.1101	0.6859	1.0485	0.9800	1.3083
FRA	0.0114	0.0211	0.1228	0.1844	0.1868	0.2459	0.0278	0.0516	0.3185	0.4883	0.4870	0.6532
GRC	0.0112	0.0208	0.1442	0.2177	0.1842	0.2439	0.0196	0.0363	0.2584	0.3924	1.0831	1.4490
HRV	0.0142	0.0262	0.2102	0.3145	0.3596	0.4724	0.0339	0.0629	1.0361	1.6396	1.8874	2.6121
HUN	0.0215	0.0398	0.2454	0.3688	0.4025	0.5308	0.0587	0.1090	0.7939	1.2232	1.3292	1.7925
IRL	0.0009	0.0017	0.0950	0.1405	0.1813	0.2364	0.0071	0.0132	0.5016	0.7931	0.9116	1.2627
ITA	0.0142	0.0263	0.1632	0.2451	0.2531	0.3332	0.0326	0.0605	0.5103	0.7892	0.8194	1.1104
LTU	0.0156	0.0288	0.2535	0.3815	0.3403	0.4485	0.0686	0.1274	0.8815	1.3475	1.1825	1.5802
LUX	0.0013	0.0025	0.0145	0.0220	0.0522	0.0696	0.0022	0.0040	0.0362	0.0555	0.0446	0.0599
LVA	-0.0043	-0.0079	-0.0070	-0.0106	0.0212	0.0283	-0.0112	-0.0208	0.0483	0.0792	0.5458	0.7377
MLT	0.0005	0.0009	0.0056	0.0084	0.0475	0.0633	-0.0026	-0.0048	-0.0048	-0.0076	-0.1677	-0.2305
NLD	0.0206	0.0381	0.1990	0.2988	0.2854	0.3755	0.0603	0.1120	0.5086	0.7774	0.6902	0.9230
POL	0.0182	0.0336	0.2161	0.3247	0.3756	0.4956	0.0438	0.0813	0.6532	1.0070	1.1259	1.5190
PRT	0.0142	0.0263	0.1515	0.2280	0.2218	0.2927	0.0335	0.0621	0.5278	0.8147	0.6969	0.9409
ROU	0.0223	0.0412	0.2836	0.4269	0.4077	0.5380	0.0730	0.1355	0.9619	1.4755	1.3676	1.8354
SVK	0.0228	0.0422	0.2792	0.4195	0.4270	0.5625	0.0602	0.1118	0.8874	1.3662	1.4536	1.9604
SVN	0.0062	0.0115	0.0735	0.1106	0.1374	0.1815	0.0144	0.0267	0.2473	0.3857	0.5313	0.7230
SWE	0.0165	0.0306	0.1981	0.2980	0.3081	0.4063	0.0446	0.0828	0.5196	0.7948	0.7727	1.0350
ALB	-0.0510	-0.0943	-0.6245	-0.9348	-0.8905	-1.1693	-0.0510	-0.0944	-0.6550	-0.9825	-0.8510	-1.1195
ARE	-0.0163	-0.0301	-0.1666	-0.2493	-0.2241	-0.2938	-0.0294	-0.0546	-0.3228	-0.4926	-0.4668	-0.6253
ARG	-0.0058	-0.0107	-0.0714	-0.1067	-0.1072	-0.1405	-0.0157	-0.0291	-0.2000	-0.3068	-0.3201	-0.4304
ARM	-0.0131	-0.0242	-0.1098	-0.1651	-0.1418	-0.1870	-0.0168	-0.0311	-0.1542	-0.2335	-0.1650	-0.2189
AUS	-0.0018	-0.0034	-0.0267	-0.0399	-0.0358	-0.0469	-0.0069	-0.0127	-0.1033	-0.1592	-0.1627	-0.2198
AZE	-0.0273	-0.0506	-0.3548	-0.5303	-0.3498	-0.4562	-0.0427	-0.0791	-0.6227	-0.9476	-0.7182	-0.9605
BGD	-0.0116	-0.0215	-0.1015	-0.1524	-0.1145	-0.1502	-0.0226	-0.0419	-0.2020	-0.3075	-0.2603	-0.3476
BHR	-0.0208	-0.0385	-0.2664	-0.3981	-0.3729	-0.4882	-0.0300	-0.0557	-0.4606	-0.7026	-0.6668	-0.8929
BLR	-0.0774	-0.1433	-0.8724	-1.3085	-1.2281	-1.6137	-0.0872	-0.1615	-1.0362	-1.5641	-1.3810	-1.8268
BOL	-0.0032	-0.0059	-0.0768	-0.1144	-0.0920	-0.1200	-0.0076	-0.0141	-0.1843	-0.2822	-0.2838	-0.3816
BRA	-0.0053	-0.0098	-0.0637	-0.0953	-0.0914	-0.1198	-0.0132	-0.0245	-0.1701	-0.2607	-0.2635	-0.3539
BWA	0.0048	0.0088	0.0530	0.0793	0.0245	0.0312	0.0095	0.0176	0.0978	0.1488	0.0720	0.0961
CAN	0.0034	0.0064	0.0380	0.0569	0.0589	0.0776	0.0033	0.0061	0.0391	0.0589	0.0595	0.0792
CHE	0.0032	0.0060	0.0580	0.0870	0.1136	0.1496	0.0034	0.0063	0.0428	0.0636	0.0994	0.1314
CHL	0.0032	0.0059	0.0452	0.0677	0.0373	0.0487	-0.0010	-0.0019	-0.0271	-0.0448	-0.0995	-0.1370
CHN	-0.0020	-0.0037	-0.0194	-0.0290	-0.0392	-0.0517	-0.0063	-0.0116	-0.0669	-0.1030	-0.1327	-0.1785
CIV	-0.0392	-0.0726	-0.5434	-0.8113	-0.7163	-0.9365	-0.0587	-0.1088	-0.9522	-1.4464	-1.2940	-1.7254
CMR	-0.0338	-0.0625	-0.4829	-0.7217	-0.6730	-0.8811	-0.0536	-0.0995	-0.8793	-1.3373	-1.2760	-1.7023
COL	-0.0051	-0.0094	-0.0856	-0.1276	-0.1280	-0.1673	-0.0077	-0.0143	-0.1790	-0.2736	-0.2799	-0.3754
CRI	-0.0068	-0.0127	-0.0781	-0.1167	-0.1579	-0.2077	-0.0125	-0.0233	-0.1719	-0.2625	-0.3403	-0.4553
ECU	-0.0045	-0.0083	-0.0892	-0.1329	-0.1023	-0.1333	-0.0103	-0.0190	-0.2183	-0.3344	-0.3239	-0.4356
EGY	-0.0312	-0.0577	-0.3760	-0.5630	-0.5176	-0.6790	-0.0477	-0.0884	-0.6614	-1.0072	-0.9382	-1.2533
ETH	-0.0098	-0.0181	-0.0963	-0.1448	-0.0933	-0.1229	-0.0126	-0.0233	-0.1326	-0.2002	-0.0823	-0.1084
GBR	0.0080	0.0149	0.0914	0.1369	0.1442	0.1894	0.0099	0.0183	0.0996	0.1501	0.2260	0.3004
GEO	-0.0067	-0.0124	-0.0586	-0.0881	-0.1043	-0.1380	-0.0085	-0.0157	-0.0781	-0.1182	-0.1233	-0.1640
GHA	-0.0189	-0.0349	-0.2316	-0.3461	-0.2879	-0.3767	-0.0300	-0.0557	-0.4432	-0.6744	-0.5614	-0.7499
GTM	-0.0028	-0.0051	-0.0492	-0.0737	-0.0674	-0.0886	-0.0036	-0.0066	-0.0733	-0.1110	-0.0999	-0.1328

contd.

Table A.6 / Continued

(d) CO_2 emissions, change in %

	CBAM limited to carbon tariffs						CBAM including carbon tariffs and export rebates					
	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal
	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)
HKG	0.0002	0.0003	0.0033	0.0050	-0.0057	-0.0076	0.0006	0.0010	0.0083	0.0126	-0.0171	-0.0228
HND	-0.0045	-0.0083	-0.0554	-0.0832	-0.0906	-0.1195	-0.0073	-0.0135	-0.0879	-0.1334	-0.1512	-0.2014
IDN	-0.0006	-0.0011	-0.0058	-0.0087	-0.0091	-0.0119	-0.0063	-0.0118	-0.0917	-0.1427	-0.1691	-0.2298
IND	-0.0071	-0.0132	-0.0733	-0.1097	-0.1072	-0.1405	-0.0155	-0.0287	-0.1691	-0.2586	-0.2630	-0.3526
IRN	-0.0112	-0.0207	-0.1293	-0.1933	-0.1235	-0.1612	-0.0247	-0.0458	-0.3399	-0.5211	-0.4463	-0.6012
ISR	-0.0326	-0.0603	-0.4110	-0.6145	-0.6182	-0.8105	-0.0511	-0.0947	-0.7387	-1.1238	-1.1207	-1.4952
JPN	-0.0037	-0.0068	-0.0338	-0.0505	-0.0452	-0.0593	-0.0088	-0.0163	-0.0895	-0.1371	-0.1326	-0.1780
KAZ	-0.0146	-0.0270	-0.1760	-0.2633	-0.2307	-0.3022	-0.0236	-0.0437	-0.3163	-0.4816	-0.4303	-0.5749
KEN	-0.0192	-0.0356	-0.2642	-0.3948	-0.3361	-0.4397	-0.0299	-0.0555	-0.5115	-0.7786	-0.6547	-0.8746
KGZ	-0.0003	-0.0006	-0.0041	-0.0061	-0.0140	-0.0183	0.0012	0.0023	0.0069	0.0113	0.0199	0.0278
KHM	-0.0017	-0.0032	-0.0143	-0.0216	-0.0624	-0.0827	-0.0035	-0.0065	-0.0308	-0.0472	-0.1569	-0.2100
KOR	-0.0005	-0.0010	-0.0045	-0.0067	-0.0218	-0.0289	-0.0056	-0.0104	-0.0456	-0.0701	-0.0913	-0.1225
KWT	-0.0240	-0.0444	-0.3460	-0.5166	-0.3938	-0.5139	-0.0373	-0.0692	-0.6226	-0.9489	-0.7996	-1.0706
LAO	-0.0050	-0.0092	-0.0840	-0.1252	-0.1229	-0.1608	-0.0082	-0.0152	-0.1586	-0.2416	-0.2563	-0.3429
LKA	-0.0062	-0.0115	-0.1001	-0.1495	-0.1582	-0.2074	-0.0105	-0.0195	-0.2027	-0.3092	-0.3454	-0.4621
MAR	-0.0406	-0.0751	-0.6463	-0.9656	-1.0127	-1.3277	-0.0580	-0.1076	-1.0425	-1.5791	-1.6340	-2.1719
MDG	-0.0097	-0.0179	-0.1094	-0.1638	-0.1587	-0.2088	-0.0130	-0.0242	-0.1651	-0.2503	-0.2485	-0.3313
MEX	-0.0051	-0.0094	-0.0510	-0.0764	-0.0807	-0.1059	-0.0145	-0.0269	-0.1615	-0.2481	-0.2797	-0.3763
MNG	-0.0013	-0.0024	-0.0132	-0.0197	0.0358	0.0476	-0.0005	-0.0010	-0.0031	-0.0039	0.0784	0.1054
MOZ	-0.0312	-0.0577	-0.4747	-0.7114	-0.5070	-0.6643	-0.0428	-0.0794	-0.6947	-1.0529	-0.6689	-0.8878
MUS	-0.0021	-0.0038	-0.0120	-0.0183	-0.0710	-0.0946	-0.0022	-0.0041	-0.0149	-0.0225	-0.1217	-0.1626
MWI	-0.0093	-0.0173	-0.0896	-0.1341	-0.0931	-0.1222	-0.0146	-0.0271	-0.1510	-0.2293	-0.1722	-0.2300
MYS	-0.0047	-0.0088	-0.0489	-0.0732	-0.1057	-0.1393	-0.0117	-0.0216	-0.1432	-0.2201	-0.2998	-0.4028
NAM	0.0089	0.0165	0.0819	0.1226	-0.0282	-0.0388	0.0144	0.0267	0.1245	0.1884	-0.0446	-0.0603
NGA	-0.0047	-0.0086	-0.0860	-0.1280	-0.0363	-0.0459	-0.0187	-0.0346	-0.3584	-0.5502	-0.4730	-0.6387
NIC	-0.0059	-0.0108	-0.1057	-0.1577	-0.1338	-0.1748	-0.0113	-0.0209	-0.2146	-0.3272	-0.3082	-0.4127
NOR	0.0134	0.0247	0.1707	0.2559	0.1391	0.1788	0.0183	0.0338	0.1999	0.3022	0.2887	0.3821
NPL	-0.0050	-0.0092	-0.0470	-0.0704	-0.0533	-0.0699	-0.0075	-0.0139	-0.0702	-0.1062	-0.0655	-0.0866
NZL	0.0003	0.0006	0.0103	0.0154	-0.0039	-0.0054	-0.0012	-0.0022	-0.0159	-0.0250	-0.0341	-0.0462
OMN	-0.0117	-0.0217	-0.1354	-0.2023	-0.0781	-0.1007	-0.0215	-0.0399	-0.2674	-0.4078	-0.2618	-0.3515
PAK	-0.0121	-0.0223	-0.1189	-0.1781	-0.1391	-0.1821	-0.0225	-0.0417	-0.2393	-0.3645	-0.2980	-0.3983
PAN	0.0032	0.0058	0.0116	0.0174	-0.0073	-0.0101	0.0072	0.0133	0.0380	0.0587	0.0295	0.0405
PER	-0.0101	-0.0187	-0.1624	-0.2426	-0.2266	-0.2966	-0.0171	-0.0317	-0.3331	-0.5088	-0.5020	-0.6725
PHL	-0.0072	-0.0134	-0.0803	-0.1201	-0.1631	-0.2145	-0.0152	-0.0281	-0.2037	-0.3121	-0.3998	-0.5361
PRY	0.0045	0.0084	0.0024	0.0038	-0.0107	-0.0146	0.0102	0.0190	0.0319	0.0494	0.0112	0.0156
QAT	-0.0278	-0.0515	-0.2382	-0.3570	-0.2853	-0.3745	-0.0515	-0.0954	-0.4646	-0.7086	-0.6009	-0.8045
RUS	-0.0241	-0.0446	-0.2630	-0.3938	-0.3488	-0.4573	-0.0370	-0.0686	-0.4114	-0.6245	-0.5511	-0.7339
SAU	-0.0141	-0.0262	-0.1450	-0.2169	-0.1192	-0.1554	-0.0309	-0.0574	-0.3611	-0.5536	-0.4478	-0.6036
SEN	-0.0270	-0.0500	-0.3986	-0.5950	-0.5202	-0.6801	-0.0388	-0.0719	-0.6476	-0.9810	-0.8864	-1.1789
SGP	-0.0126	-0.0234	-0.1401	-0.2093	-0.2132	-0.2795	-0.0251	-0.0466	-0.3109	-0.4752	-0.4987	-0.6680
SLV	-0.0091	-0.0168	-0.1200	-0.1793	-0.1546	-0.2021	-0.0174	-0.0322	-0.2542	-0.3878	-0.3499	-0.4684
THA	-0.0065	-0.0121	-0.0704	-0.1053	-0.1329	-0.1747	-0.0143	-0.0265	-0.1770	-0.2713	-0.3424	-0.4596
TUN	-0.0374	-0.0693	-0.5305	-0.7929	-0.7952	-1.0424	-0.0463	-0.0858	-0.6928	-1.0441	-1.0854	-1.4369
TUR	-0.0255	-0.0473	-0.3063	-0.4588	-0.4828	-0.6345	-0.0401	-0.0743	-0.5434	-0.8265	-0.8578	-1.1442
TWN	-0.0091	-0.0169	-0.0765	-0.1146	-0.1145	-0.1503	-0.0218	-0.0404	-0.2045	-0.3134	-0.3323	-0.4461
TZA	-0.0041	-0.0075	-0.0493	-0.0741	-0.0446	-0.0587	-0.0046	-0.0086	-0.0760	-0.1151	-0.0384	-0.0505
UGA	-0.0110	-0.0204	-0.0889	-0.1336	-0.1111	-0.1464	-0.0167	-0.0310	-0.1471	-0.2236	-0.1916	-0.2559
UKR	-0.0447	-0.0828	-0.5260	-0.7893	-0.6912	-0.9082	-0.0592	-0.1098	-0.7558	-1.1463	-0.9551	-1.2697
URY	-0.0099	-0.0183	-0.1503	-0.2244	-0.2121	-0.2774	-0.0175	-0.0324	-0.2862	-0.4358	-0.4135	-0.5523
USA	-0.0017	-0.0032	-0.0173	-0.0258	-0.0292	-0.0383	-0.0038	-0.0070	-0.0418	-0.0640	-0.0773	-0.1037
VEN	-0.0197	-0.0365	-0.2774	-0.4142	-0.3746	-0.4899	-0.0266	-0.0493	-0.4277	-0.6491	-0.5981	-0.7966
VNM	-0.0022	-0.0041	-0.0215	-0.0324	-0.0317	-0.0420	-0.0056	-0.0104	-0.0541	-0.0826	-0.1092	-0.1461

contd.

Table A.6 / Continued

(d) CO_2 emissions, change in %

	CBAM limited to carbon tariffs						CBAM including carbon tariffs and export rebates					
	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal	ETS current price	ETS future price		IMF tax		Stiglitz-Stern-tax proposal
	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)	current coverage, with free allowances	current coverage, with free allowances	current coverage, without free allowances	current coverage, without free allowances	full coverage (all sectors)	full coverage (all sectors)
XAC	-0.0153	-0.0283	-0.1936	-0.2892	-0.0888	-0.1137	-0.0371	-0.0689	-0.5562	-0.8509	-0.5961	-0.8027
XCA	-0.0044	-0.0081	-0.1197	-0.1781	-0.2015	-0.2635	-0.0066	-0.0122	-0.2182	-0.3318	-0.3920	-0.5233
XCB	-0.0103	-0.0191	-0.1452	-0.2165	-0.2037	-0.2661	-0.0158	-0.0293	-0.2497	-0.3797	-0.3712	-0.4955
XCF	-0.0211	-0.0390	-0.2526	-0.3776	-0.2642	-0.3450	-0.0375	-0.0695	-0.5533	-0.8440	-0.6942	-0.9302
XEA	-0.0009	-0.0016	-0.0095	-0.0142	0.0127	0.0172	-0.0022	-0.0041	-0.0158	-0.0239	0.0070	0.0094
XEC	-0.0082	-0.0153	-0.1023	-0.1529	-0.1924	-0.2531	-0.0149	-0.0277	-0.2358	-0.3610	-0.4261	-0.5718
XEE	-0.0043	-0.0079	-0.0157	-0.0238	-0.0339	-0.0450	-0.0081	-0.0150	-0.0456	-0.0703	-0.1241	-0.1670
XEF	-0.0530	-0.0981	-0.8902	-1.3328	-1.2684	-1.6645	-0.0584	-0.1081	-1.0399	-1.5652	-1.4124	-1.8648
XER	-0.0593	-0.1097	-0.6976	-1.0446	-0.9554	-1.2533	-0.0731	-0.1354	-0.9450	-1.4274	-1.2699	-1.6825
XNA	-0.0386	-0.0715	-0.5525	-0.8248	-0.7852	-1.0271	-0.0436	-0.0807	-0.6806	-1.0248	-0.9366	-1.2371
XNF	-0.0571	-0.1057	-0.7386	-1.1040	-0.8475	-1.1080	-0.0805	-0.1492	-1.1823	-1.7940	-1.4769	-1.9678
XOC	-0.0050	-0.0092	-0.0596	-0.0889	-0.0594	-0.0771	-0.0115	-0.0214	-0.1592	-0.2440	-0.2170	-0.2922
XSA	-0.0144	-0.0266	-0.1931	-0.2884	-0.2623	-0.3430	-0.0193	-0.0357	-0.2891	-0.4381	-0.4051	-0.5390
XSC	-0.0096	-0.0178	-0.0865	-0.1296	-0.1225	-0.1612	-0.0177	-0.0328	-0.1636	-0.2490	-0.2577	-0.3444
XSE	-0.0053	-0.0098	-0.0591	-0.0884	-0.0603	-0.0788	-0.0112	-0.0209	-0.1419	-0.2171	-0.1978	-0.2660
XSM	-0.0120	-0.0221	-0.1973	-0.2934	-0.2750	-0.3583	-0.0161	-0.0299	-0.3248	-0.4929	-0.4943	-0.6588
XSU	-0.0079	-0.0146	-0.0959	-0.1434	-0.1114	-0.1457	-0.0122	-0.0225	-0.1691	-0.2576	-0.2263	-0.3030
XWF	-0.0107	-0.0198	-0.0862	-0.1292	-0.0817	-0.1074	-0.0184	-0.0342	-0.1969	-0.3003	-0.2424	-0.3254
XWS	-0.0152	-0.0282	-0.1676	-0.2511	-0.2014	-0.2642	-0.0294	-0.0545	-0.4044	-0.6195	-0.5477	-0.7367
ZAF	-0.0059	-0.0110	-0.0829	-0.1238	-0.1716	-0.2256	-0.0133	-0.0246	-0.2266	-0.3478	-0.4389	-0.5897
ZMB	-0.0169	-0.0312	-0.2312	-0.3467	-0.3153	-0.4141	-0.0252	-0.0467	-0.3774	-0.5742	-0.4822	-0.6427
ZWE	-0.0013	-0.0024	0.0017	0.0025	-0.0538	-0.0714	-0.0027	-0.0051	-0.0161	-0.0252	-0.1133	-0.1521
EU	0.0151	0.0280	0.1692	0.2543	0.2653	0.3497	0.0370	0.0687	0.4821	0.7420	0.8099	1.0913
Non-EU	-0.0066	-0.0121	-0.0741	-0.1108	-0.1038	-0.1362	-0.0125	-0.0232	-0.1534	-0.2342	-0.2312	-0.3096
EFTA	0.0059	0.0109	0.0699	0.1049	0.0516	0.0659	0.0085	0.0157	0.0726	0.1098	0.1239	0.1641
World	-0.0037	-0.0068	-0.0419	-0.0625	-0.0550	-0.0719	-0.0060	-0.0111	-0.0693	-0.1050	-0.0934	-0.1242

A.4 DESIGN OPTIONS FOR THE CBA

The table presents various design choices, based on Mehling et al. (2020) and Marcu et al. (2020), complemented with additional insights from literature. Most of the options included were described in relation to a European CBA and a few others come from theoretical proposals.

Table A.7 / Summary table of CBA design options

Coverage of trade flows	Imports	Exports	Imports and exports (Monjon and Quirion, 2010)	
Policy mechanism	Carbon tax (similar to VAT)	Customs duty (tariff or other fiscal measure applied at the border)	Extension of the cap-and-trade system – direct extension to foreign firms or establishment of ‘virtual emission allowances’	
Export rebates	Tax exemptions for domestic exporters	Output-based rebates (Fischer and Fox, 2012)		
Free allocation	Unaffected	Gradual phase-out	Immediately rescinded	
Scope and coverage	***Geographic*** - All countries - Exemption of least developed countries - Exemptions on environmental grounds (e.g. established carbon price, ‘adequate"’regulatory mechanism)	***Sectoral*** - Basic materials only (EITEs) - Basic materials and electricity - Basic materials, electricity, and complex products	***Emissions*** - Direct - Indirect - Power generation - other, such as transport, inputs (Cosbey et al., 2012)	***Product-based***, criteria can include: - carbon intensity - position in supply chain (downstream, upstream, or both) - complexity of the product (Monjon and Quirion, 2010)
Determining embodied emissions	Calculation at product level	***Benchmarks*** - Best practice: domestic/global - Worst practice: domestic/global - Average carbon intensity of domestic producers - Best available technology (BAT)	Voluntary individual adjustment mechanism: voluntary calculation at product level (Mehling and Ritz, 2020)	Avoided emissions (Rocchi et al., 2018)
Calculation method	No consideration of foreign policies	Consideration of foreign carbon price-based policies	Consideration of foreign carbon price-based and regulatory policies	
Use of revenue	Refund to covered domestic firms	Refund to covered foreign firms	Contribute to general revenue	Finance a domestic fund for climate innovation
Institutions and process	***Governance*** - EU - Co-operation under WTO - Establishment of international body under the IPCC	***Certification bodies*** - Only domestic bodies (centralised) - Accredited foreign bodies		

IMPRESSUM

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